The Economics and Greenhouse Gas Abatement of an Alternative Biofuel for Sugar Mills:

the case of camphor laurel (*Cinnamomum camphora* T. Nees and Eberm.) in Tweed and Byron Shires of New South Wales

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A sub-thesis submitted in partial fulfilment of the requirements for the degree of Master of Forestry

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August 2001

Declaration

I, Mahalle G. Punyalal, hereby declare that this sub-thesis is the result of my own independent research and that all references and sources that have been used are duly acknowledged.

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Acknowledgments

I would like to express my sincere thanks to my supervisor, Dr Sinniah Mahendrarajah, for his diligent, generous and wise supervision. Also, I am thankful to Dr Cris Brack for his guidance and advice in the greenhouse gas estimation part of this study.

I wish to extend my wholehearted thanks to the staff of the State Forests New South Wales at Grafton. Special thanks are due to Keith Lamb, Plantation Development Analyst, Robin Heathcoat, Business Development Manager and Janine Rudder, Field Officer, for their support of this study in various ways.

I wish to thank Professor Peter Kanowski for his encouragement and financial support for the field work.

I am also thankful to Sue Holzknecht for her editorial assistance and to my colleagues, Robert Langford, Binod Devkota and Surendra Lal Karna for their friendship and help in finalising the sub-thesis.

My graduate studies at the Australian National University was made possible by a scholarship from AusAID and study leave from Forest Department of Sri Lanka, for which I am thankful to these organizations. Last, but not least, I am grateful to my wife, Anoshika Shiwanthi, for her understanding and support which enabled me to complete this project.

Abstract

Use of environmental weeds such as camphor laurel (*Cinnamomum camphora* T. Nees and Eberm.) as fuel to generate electricity for sugar mills is one of the strategies proposed to achieve renewable energy targets in Australia. However, biomass-based renewable energy sources would also emit greenhouse gases. The present study examines the potential of camphor vegetation in Tweed and Byron Shires of New South Wales. The control of camphor laurel is important in this region because it is a declared noxious weed creating problems for landowners. A major concern with regard to its control is that Australian Greenhouse Office may identify clearing of camphor as an act of deforestation under Article 3.3 of the Kyoto Protocol. If so, the landowner or state government would be responsible for any emissions associated with the control after 2008. Neither accelerated control nor postponement of its control is acceptable.

Consequently, the State Forests New South Wales has proposed a harvest-reforestation program which would conform to Article 3.4 that allows changes in land use leading to increased sequestration of greenhouse gases. This project aims at replacing camphor laurel with eucalypts to develop a sustainable timber industry while using most of the biomass as an energy source for the two sugar mills in the area. Preliminary investigations conducted by the State Forests New South Wales have revealed that this project could lead to a favourable carbon budget. The present study has undertaken an evaluation of two alternative actions, namely retaining camphor in its natural spread and the control of camphor by implementing this project, in terms of their greenhouse gas emissions and economics. A Life cycle analysis approach was adopted to analyse greenhouse gas emissions while the economics was assessed using social benefit cost analysis.

Results of this study have revealed that controlling camphor laurel in this region is important, as leaving camphor to spread leads to a net loss to society after accounting for its carbon sequestration benefits. The results suggest that the harvest-reforestation project could reduce greenhouse gas emissions and yield net benefits to society, specially under lower discount rates. However, the emissions from residues after clearing and extraction are crucial in determining attractiveness of the project under high discount rates. Although the substitution of woodchips for coal in sugar mills leads to a considerable amount of greenhouse gas mitigation in energy generation, the high CO_2 emissions from residues on decay could reduce such benefit. The greenhouse gas reduction and net social benefits could be enhanced if these residues, specially, below-ground biomass is extracted and used in the energy generation process. However, current information on greenhouse gas emissions from these residues is insufficient to draw strong conclusions. Therefore, further studies on the crucial emissions from below ground biomass are important for State Forests New South Wales in implementing this project and in achieving national renewable energy targets.

List of Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
AGO	Australian Greenhouse Office
CBA	Cost benefit analysis
CRC	Cooperative Research Centre
FAO	Food and Agricultural Organization
FCCC	Framework Convention on Climate Change
GEF	Global Environmental Facility
GEMIS	Global Emission Model for Integrated Systems
GORCAM	Graz/Oak Ridge Carbon Accounting Model
GWP	Global Warming Potential
GWh	Giga watt hours
ha	Hectare
IEA	International Energy Agency
LCA	Life Cycle Analysis
m^3	Cubic meters
MAC	Marginal cost of abatement
MB	Marginal benefits
MJ	Mega Joule
MWh	Mega watt hours
NPV	Net present value
NSW	New South Wales
PJ	Peta Joule
TJ	Tera Joule
tC	Tonne of carbon
SFNSW	State Forests of New South Wales
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
WMO	World Meteorological Organization

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1. Chapter 1. Introduction

1.1 Background

The intensive use of fossil fuels increases the concentration of greenhouse gases (GHGs) such as carbon dioxide in the atmosphere and this increase is linked to global warming. Several countries have agreed to reduce the use of these unsustainable energy sources and to find alternatives (McCarl and Schneider, 2000, 1). The International Energy Agency (IEA) is working with its member countries including Australia to find alternative sustainable energy sources. Australia relies heavily on unsustainable energy sources, especially coal, but has committed to reduce the rise in greenhouse gas (GHG) emissions. It is exploring the potential for the use of renewable energy sources including biomass in addition to increasing carbon sinks. Camphor laurel (*Cinnamomum camphora* T. Nees and Eberm.), a noxious weed, is among the suggested alternative bioenergy sources for Australia (Biomass Taskforce, 1999a).

There are about 30,000 hectares of camphor laurel in Tweed and Byron Shires in northern NSW (SFNSW, 2000, 1), which is the focus of the present study. The State Forests New South Wales (SFNSW) is planning to control its further spread by converting infested land to forest plantation so as to develop a sustainable timber industry. However, the major concern is the implication for carbon balance due to the removal of this carbon sink, in particular, the possibility that the Australian Greenhouse Office (AGO) might identify the control of camphor laurel as an act of deforestation in relation to GHGs abatement targets. According to Article 3.3 of the Kyoto Protocol, the net changes in GHG emissions since 1990 will be used to meet the commitment to abatement during 2008-2012 (AGO 2000: 23). Therefore, SFNSW will be held responsible under this Article for emissions associated with controlling this weed after 2008.

In dealing with the issue of camphor laurel, three alternative courses of action are possible, namely, accelerated clearing, indefinite postponement or undertaking a harvest-reforestation project to control camphor that would reduce GHG emissions and increase the carbon absorption capacity of the land. Accelerated clearing is not favoured because it could lead to significant environmental and social problems (SFNSW, 2000, 1). According to the SFNSW, postponing the control of camphor laurel is also not advisable because it would create problems for land managers due to a further spread of this noxious weed. A harvest-reforestation strategy would be worthy of consideration because it has been shown in previous studies by Hall *et al.* (1990, 5) and Marland and Marland (1992, 181) that high growth rates and efficient use of biomass harvest would be a better alternative in the long run.

The SFNSW has proposed a 30-year-harvest-reforestation project aimed at utilising harvested camphor laurel biomass as timber and bioenergy, and camphor leaves to extract oil, while establishing 10,000 hectares of eucalypts and 1,000 hectares of riparian forest that would lead to increased carbon sequestration (SFNSW, 2000: 1). This may be a workable solution as Article 3.4 of the Kyoto Protocol allows for accounting changes in land use due to human activities that provide an additional sink leading to increased carbon sequestration (AGO 2000: 24). The bioenergy generated from burning camphor laurel could be a potential supplementary energy source to bagasse in operating the two sugar mills in the area (SFNSW, 2000: 2). This study aims at comparing GHG emissions associated with the deferring action and the proposed project, and the economics of these two alternatives.

1.2 State Forests Camphor Replacement Programme

1.2.1 Camphor laurel resources in NSW

Camphor laurel is a fast-growing, broad-leaved evergreen woody tree species, native to warm-temperate and sub-tropical areas of East Asia (Stubbs and Cameron, 1999, 9). Camphor was introduced into Australia during the 1860s as a shade tree along streets, parks and other public places in coastal areas of eastern Australia. Changes in land use during the 1960s from intensive dairy farming to extensive grazing of beef cattle have led to the proliferation of this tree species, especially in the Richmond-Tweed district of NSW, owing to a lack of weed control (Firth, 1980, 244 and Firth, 1981, 26). Consequently, it has been declared a noxious weed (State Government of NSW, 1999).

Figures 1.1 and 1.2 show the location of Tweed and Byron Shires in Australia and the current distribution of camphor in these Shires. Camphor vegetation in this area is scattered. This resource can be divided into three categories based on canopy dominance, namely, dominant, co-dominant and scattered crown cover. The aboveground biomass availability under these three categories in the year 2000 is shown in Table 1.1. Despite this scattered distribution, this resource has the potential for use as a bioenergy source because estimates show that more than 100,000 tonnes of biomass per year could be made available to the two sugar mills (Heathcote *et al.*, 1999, 7).

Table 1.1: **Estimated camphor biomass availability in Tweed and Byron Shires**

Category	Crown cover	Area (ha)	Biomass (t/ha)	Total Biomass (t)
Dominant	>80%	4318	395	1,705,610
Co-dominant	50-80%	4,871	305	1,485,655
Scattered	10-50%	20,991	60	1,259,460
Total		30,180		4,450,725

Source: Lamb, 2000, 1

1.2.2 Role of the two sugar mills

At present, two nearby sugar mills, Condong and Broadwater belonging to NSW Sugar Milling Co-operative Limited, use bagasse and coal as energy sources in processing sugar and these mills operate only during the harvesting and crushing period. The locations of these two sugar mills are indicated in Figure 1.2. The SFNSW has proposed to deliver processed woodchips to these two mills at a subsidised rate to generate renewable electricity. These mills plan to generate altogether 60MW of electricity (30MW by each mill) at the commencement of the project. This electricity will be supplied to the grid, and for the cogeneration plant and sugar mills (Sunshine Energy, 2000, 3). During the cane-crushing period, these mills will use mainly bagasse and cane leaves while woodchips and cane leaves will be used during the non-crushing period (from December to June). It has been estimated that about 100,000 tonnes of woodchips and 100,000 tonnes of cane leaves are required by each mill to operate the boilers (Sunshine Energy, 2000, 17). The boilers' capacities will be upgraded to burn woodchips and cane leaves (SFNSW, 1999b, 27).

Figure 1.1: **Location of the camphor laurel project area, northern New South Wales**

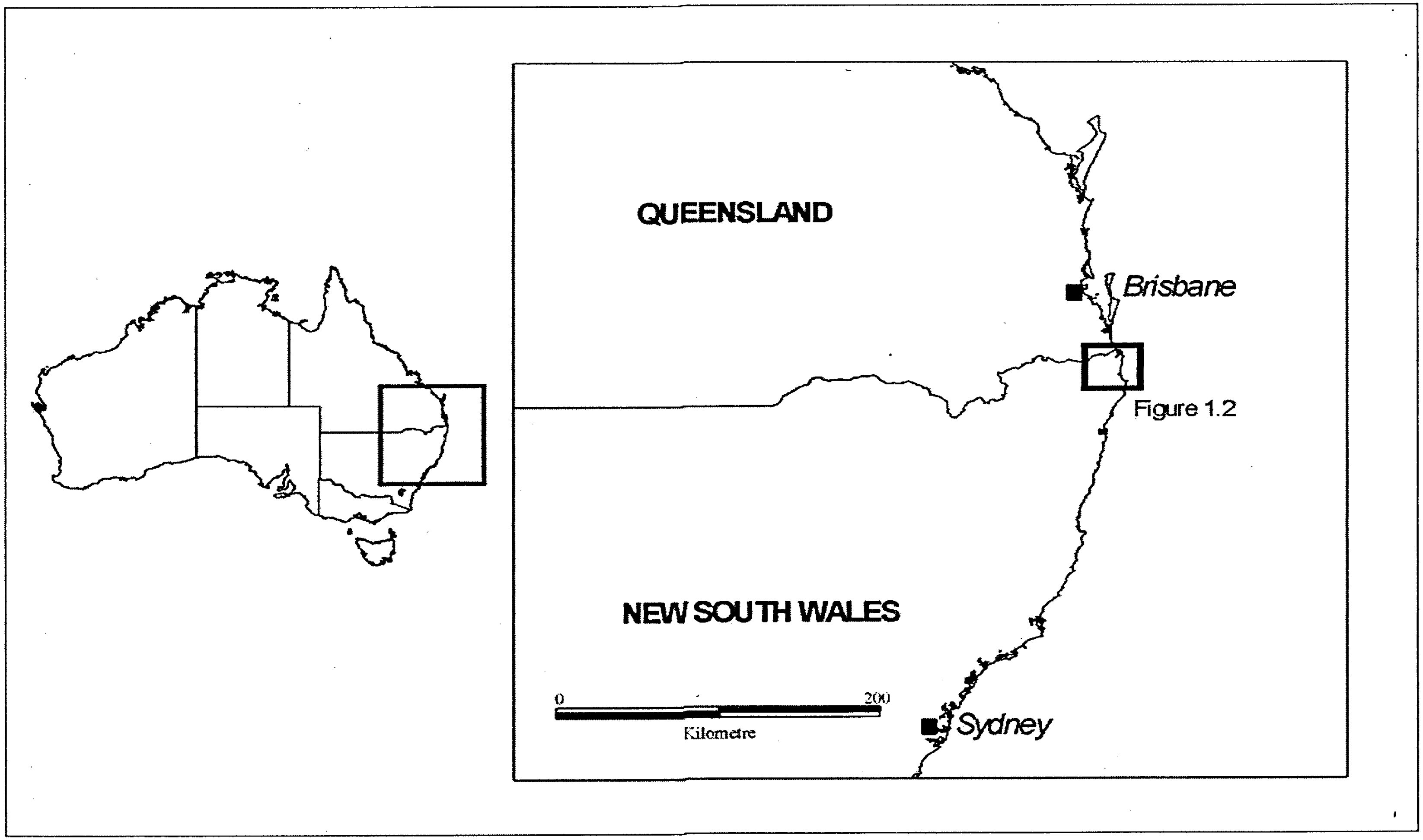
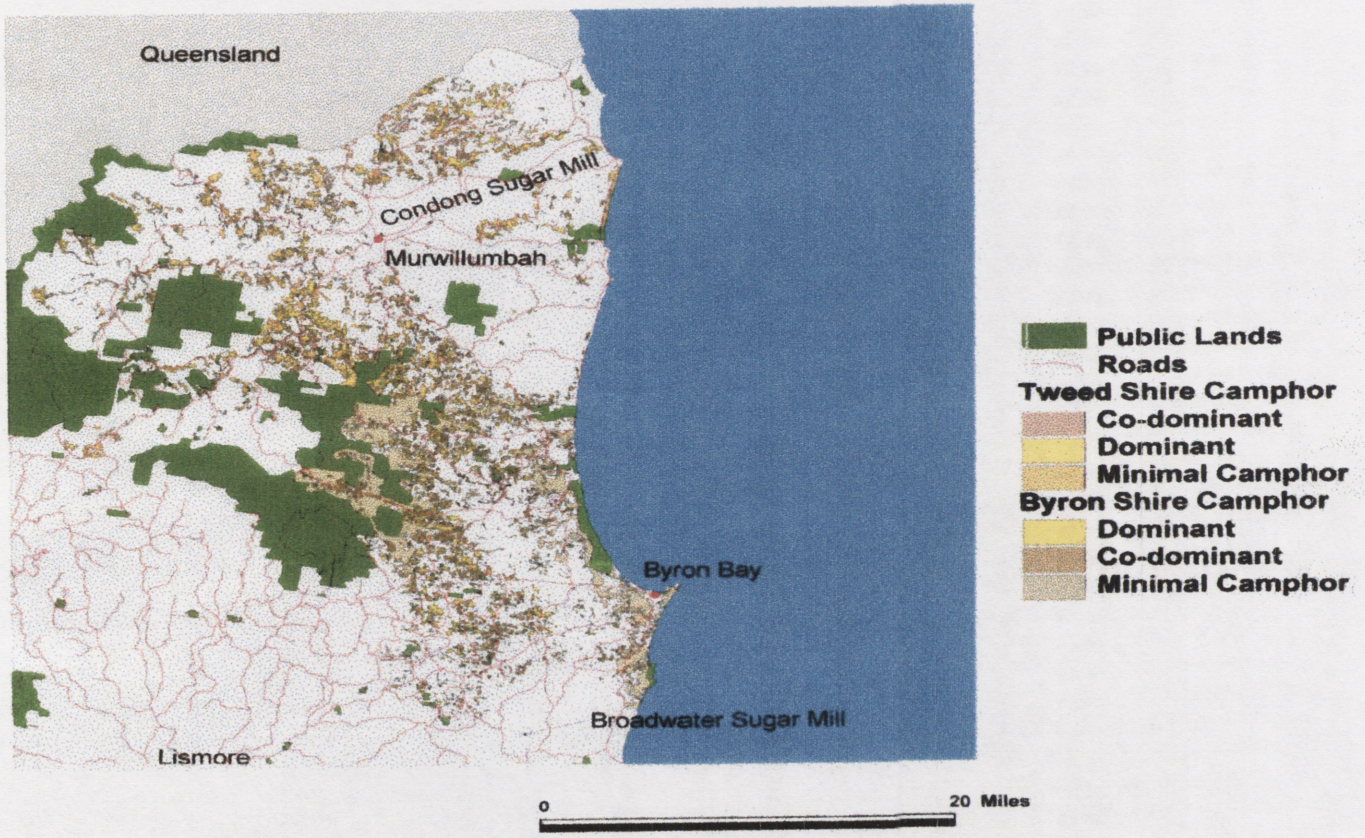


Figure 1.1: **Distribution of camphor laurel in Tweed and Byron Shires of New South Wales**



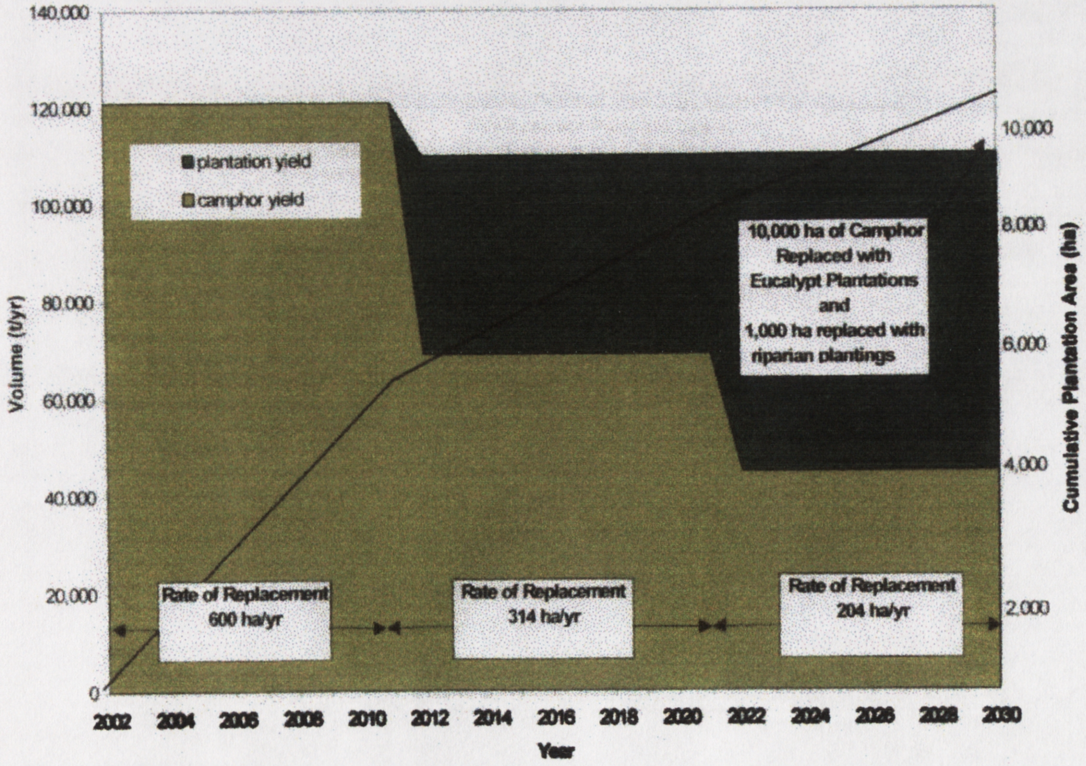
Source: SFNSW, 2000

1.2.3 Camphor replacement programme versus deferring control action

The project aims at utilising 11,000 hectares of camphor over a 30-year-period. The project has three distinct phases and in the early phases camphor would be replaced by more intensive planting of eucalypts. This replacement plan is depicted in Figure 1.3. It would commence at 600 hectares per year during the first 10 years, about 300 hectares per year during the next 10 years and then drop to about 200 hectares per year during the rest of the project period (SFNSW 2000, 2).

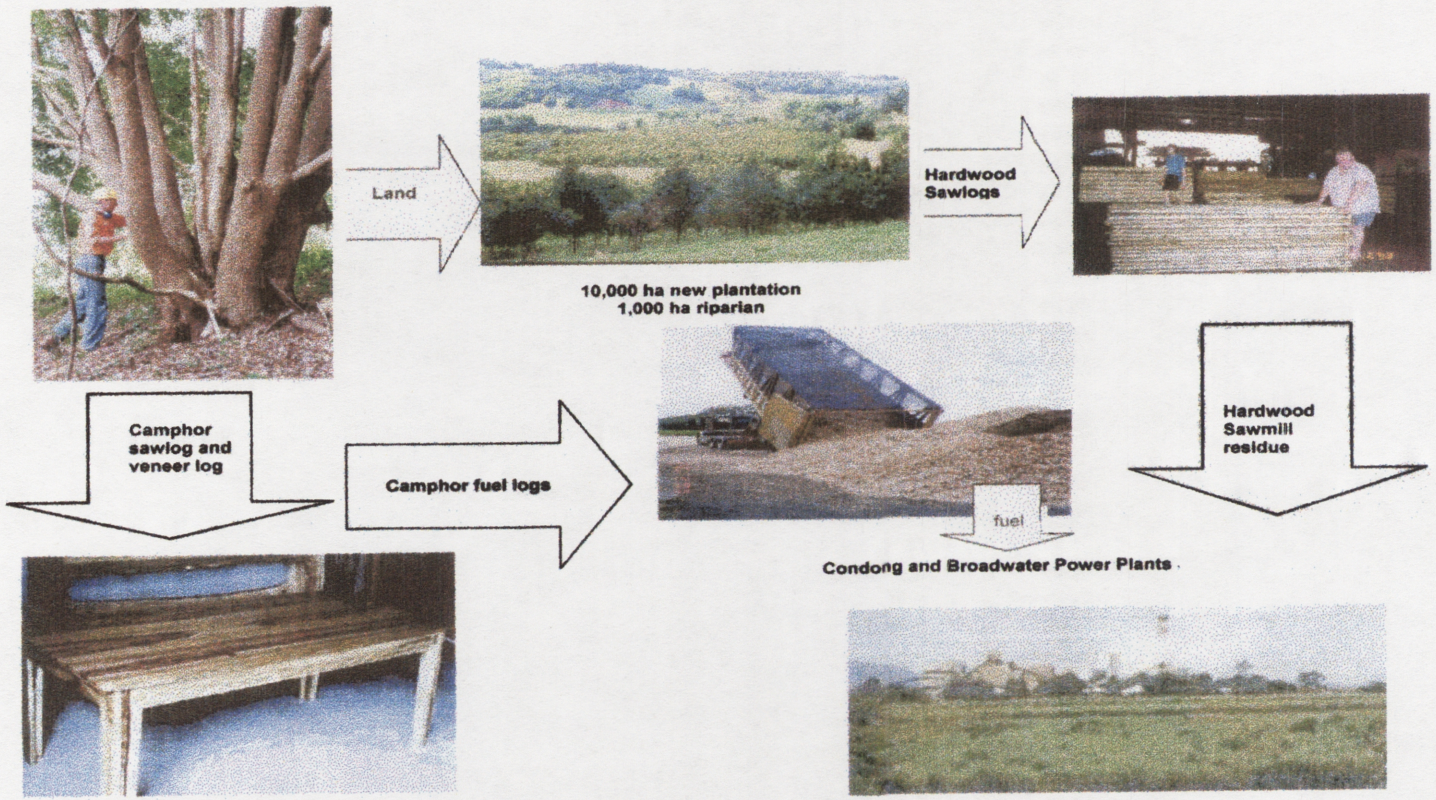
Figure 1.4 is a schematic representation of the project. Of the harvested camphor, about 10 per cent of the total above-ground woody camphor biomass would be used for timber while the rest would be chipped and transported to the sugar mills for bioenergy. The leafy biomass will be used in production of camphor oil. In addition to woodchips, these two sugar mills would use sawmill residues from processing of this timber. The SFNSW (2000, 5) has completed a preliminary investigation and has identified a number of the merits of the project, as summarised in Box 1.1 below.

Figure 1.3: **Annual volume and area plan of the harvest-reforestation project**



Source: **SFNSW, 2000, 3**

Figure 1.4: **Camphor replacement project of the State Forests New South Wales**



Source: **SFNSW, 2000**

Box 1.1: **Merits of the project**

(I)	Benefits of additional carbon sequestration due to new, more productive eucalypt plantations than camphor, on the one hand, and GHG abatement at sugar mills using camphor as bioenergy on the other.
(II)	Employment benefits for about 200 persons from the following expected employment opportunities with the implementation of the project:
(a)	10 positions for the acquisition, harvesting, chipping and transport of camphor for energy generation.
(b)	40 positions in secondary processing of wood products.
(c)	8 positions in the production of camphor oil products.
(d)	10 positions for the establishment and management of plantations.
(e)	5 positions for the establishment and management of riparian forests.
(f)	About 100 positions for the secondary processing of plantation products
(III)	Control of some of the camphor in the area and replace them with native environmentally friendly local species.
(IV)	Long term carbon storage from wood processed into goods from both camphor and eucalypts, and from the proposed establishment of riparian forests.

Source: SFNSW (2000, 5)

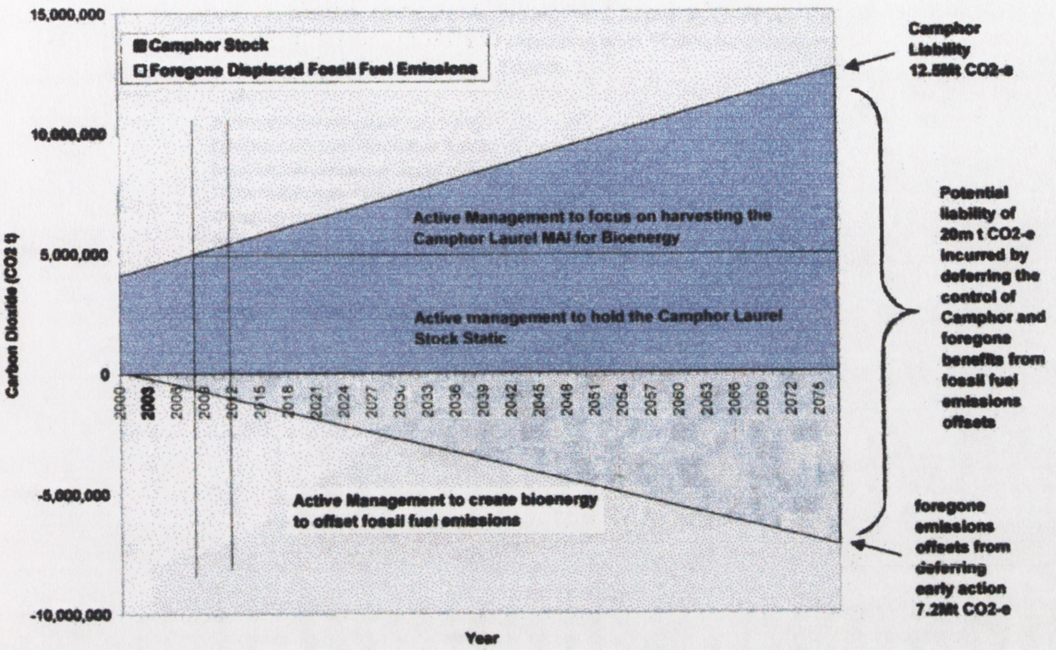
The SFNSW has identified the following costs (summarised in Box 1.2) of not undertaking the project and hence deferring the control of camphor laurel.

Box 1.2: **Costs of not undertaking the project**

(I)	Loss of income for the landowners. It has been estimated that the annual losses of income for landowners in the camphor area under the scattered crown cover is $100 per hectare while the annual loss under the dominant and co-dominant crown covers is $150 per hectare.
(II)	Increase in future clearing costs due to the growth of camphor vegetation. The estimated annualized costs of clearing for the dominant, co-dominant and scattered crown covers are $32.50, $15 and $1 per hectare respectively.
(III)	The future expansion of camphor-infested areas and associated increase in costs, which have not been estimated by SFNSW.
(IV)	Control liability of about 20 million tonnes of CO_2 equivalents for an 80-year period. This CO_2 liability due to continued growth of camphor (about 12.5 million tonnes) and foregone fossil fuel offsets (about 12.5 million tonnes) are depicted in Figure 1.5. The estimated value of this liability is $30 million.

Source: SFNSW, 2000, 5

Figure 1.5: **Camphor laurel liabilities and foregone fossil fuel offsets of the deferring action**



Source: SFNSW, 2000, 3

The results of this preliminary investigation have revealed that this camphor replacement programme would be the best solution. The CO_2 emissions of the three energy sources are shown in Table 1.2. Bagasse and wood emit considerably less amount of CO_2 than coal. Although there is potential to mitigate considerable amount of CO_2 emissions by substituting wood for coal, the effect of other GHG emissions such as nitrous oxide (N_2O) and methane (CH_4) should be considered in evaluating the overall effect. However, SFNSW has not taken into account the other GHGs in estimating GHG benefits of the project. It is not known whether this additional information is significant in relation to GHG abatement. Therefore, a detailed investigation of GHG emissions considering all the relevant GHGs and an economic assessment of these two alternatives would be necessary in making a decision.

Table 1.2: **Carbon dioxide emissions of the three energy sources**

Energy Source	tC as CO_2 per TJ
Bagasse	109,293
Coal (Australia)	968,860
Wood (generic)	107,777

Source: *Oeko-Institut*, 2000b

1.3 Research Objectives

The control of camphor laurel is expected to lead to direct benefits for farmers and to reduce net GHG emissions, especially if the biomass from camphor and eucalypts can be used as bioenergy in the two sugar mills. The main issue being addressed is whether undertaking such projects would yield net benefits also taking into account carbon sequestration. A related issue is whether undertaking the project would reduce the amount of GHG emissions. The study will focus on the control of camphor laurel in Tweed and Byron Shires to investigate the above issues. As described above, this study is linked to the proposed harvest-reforestation project in the region. The specific objectives of this study are:

(I) The estimation of all the relevant GHG emissions in all the steps of the proposed project.

(II) An evaluation of the economic benefits of the two alternatives identified by SFNSW.

The latter assessment will highlight the level of net social benefits from the control of camphor laurel and it can also be used as a basis for choosing between the alternatives. In order to achieve these objectives, the following methods were adopted.

Life Cycle Assessment (LCA) was adopted to assess the GHG emissions of the project. This technique is capable of accounting all emissions of GHGs in all the steps from extraction through to end-use in both the fossil fuel plus bagasse system and the woodchips plus by-products from the sugarcane industry. Total emissions in all steps from production through conversion in power plants of these two energy generation systems can be assessed.

In the evaluation of economic benefits, the present value of net social benefits or net present value is a useful measure to evaluate projects in relation to their carbon emission mitigation efficiency. Benefit cost analysis was performed to estimate the present value of net social benefits.

1.4 Data collection

Data required for the study were collected from secondary sources and through a literature survey. In addition, a field visit was made in March 2001 to camphor-infested areas and the two sugar mills. During the visit, project staff of the SFNSW were also interviewed. This field study was useful to understand how the project would be implemented, to collect information on energy sources used by the two sugar mills and unpublished data of the SFNSW, and to obtain the views of the project staff. However, some of the data, such as technical data pertaining to energy generation by the sugar mills and capital investment on the project was not available for the study due to commercial confidentiality. Therefore, default data suggested by SFNSW was used in the analysis. Secondary data in the GEMIS (Global Emission Model for Integrated Systems) database (*Oeko-Institut*, 2000a) was used for the estimation of GHG emissions. The oil extraction from camphor laurel leaves would not be included in this study due to lack of data.

1.5 Outline of the study

This thesis has been divided into five chapters. Chapter 1 describes the problems arising from spreading camphor laurel in Tweed and Byron Shires of NSW, the need to control this noxious weed and the associated problems of GHG emissions, and the details of the proposed harvest-reforestation project. It also outlines the objectives and the methods used for data collection for the study. Chapter 2 summarises avenues of carbon emissions and abatement under the two alternative actions and presents a review of literature pertaining to global CO_2 emissions and the position of Australia, the potential of bioenergy in Australia's national greenhouse strategy, the camphor laurel in the region, and the approaches used to evaluate GHG emissions and economics of the alternative actions. The methods used to estimate GHG emissions and the economics of the alternative actions, and the results of the study are presented in Chapters 3 and 4 respectively. Chapter 5 provides a summary of the study and the main conclusions.

2. Chapter 2. Nature of the Problem and Approaches

This chapter is divided into four sections. Section 1 describes the magnitude of the anthropogenic effect of global warming, related treaties and Australia's commitment. In the second section, it examines the scope for reducing the level of carbon emissions in Australia through biomass energy with reference to camphor laurel. Section 3 sets out the nature of control options for camphor laurel and its implications to carbon emissions. Section 4 discusses an approach for economic assessment of carbon emissions reduction with the use of camphor laurel.

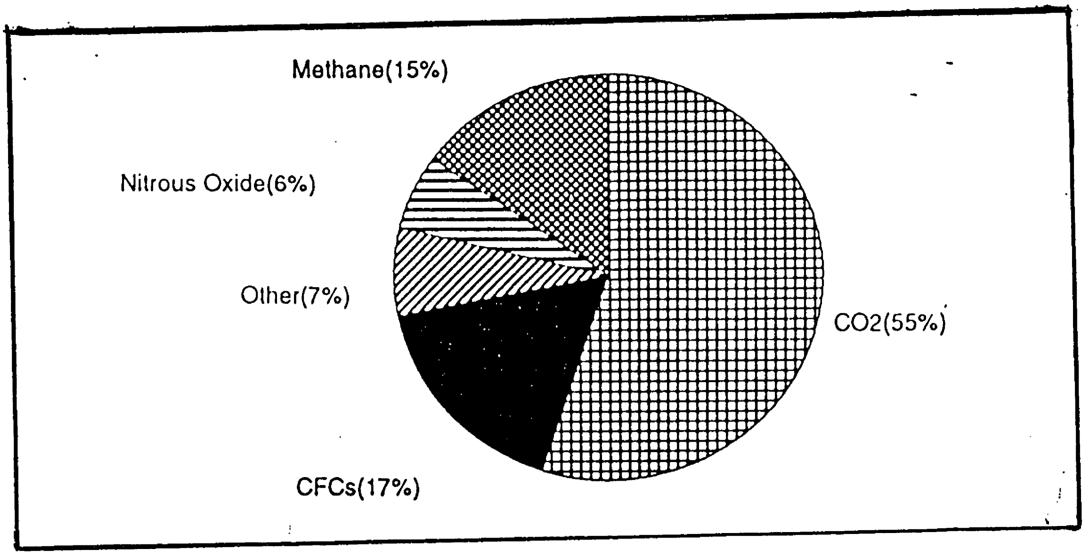
2 1 Greenhouse gas emissions and climate change

2.1.1 Greenhouse gas induced climate change

Gases such as CO_2, CH_4, N_2O, CFSs (halocarbons) and ozone (O_3) provide a warming blanket in the atmosphere by absorbing thermal infrared radiation emitted by the earth surface and atmosphere. According to MacDonald (1990), changes in the atmospheric concentration of these gases due to human activities could cause changes in the environment at the global level. Present and past changes in concentrations of some gases have influenced the atmospheric thermal budget. These gases contribute significantly to the greenhouse effect and their atmospheric concentration, which is an important determinant of the thermal budget. An increase in concentration causes upward-shifts in the global equilibrium average atmospheric temperature (MacDonald, 1990, 1-20).

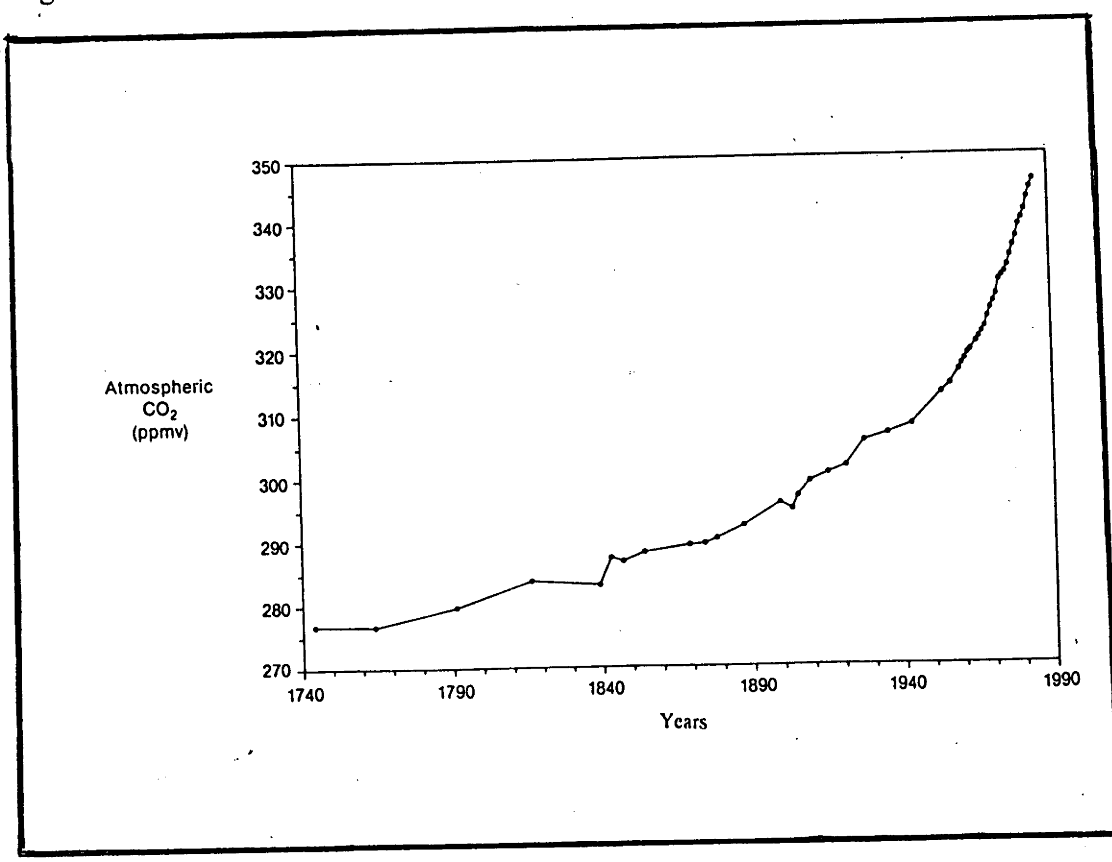
Figure 2.1 shows the principal GHGs and their relative contributions to the anthropogenic greenhouse effect. The CO_2 is the largest contributor to this effect and accounts for about half of the global warming effect (Duraiappah, 1993, 34; GEF, 1992, 5). Figure 2.2 shows how the global atmospheric CO_2 has increased over the past two centuries. There is an exponential increase in CO_2 in the atmosphere. The atmospheric CO_2 concentration has increased from 315 to 350 ppm during the 30 year period from 1960 to 1990, corresponding to an addition of 74.3 giga tonnes (Gt) of carbon to the atmosphere. The change in average global temperature over the past 110 year period is depicted in Figure 2.3. There has been a general tendency of warming of about 0.5^0C over the past century (MacDonald, 1990, 1-20).

Figure 2.1: **Relative contributions of the major greenhouse gases**



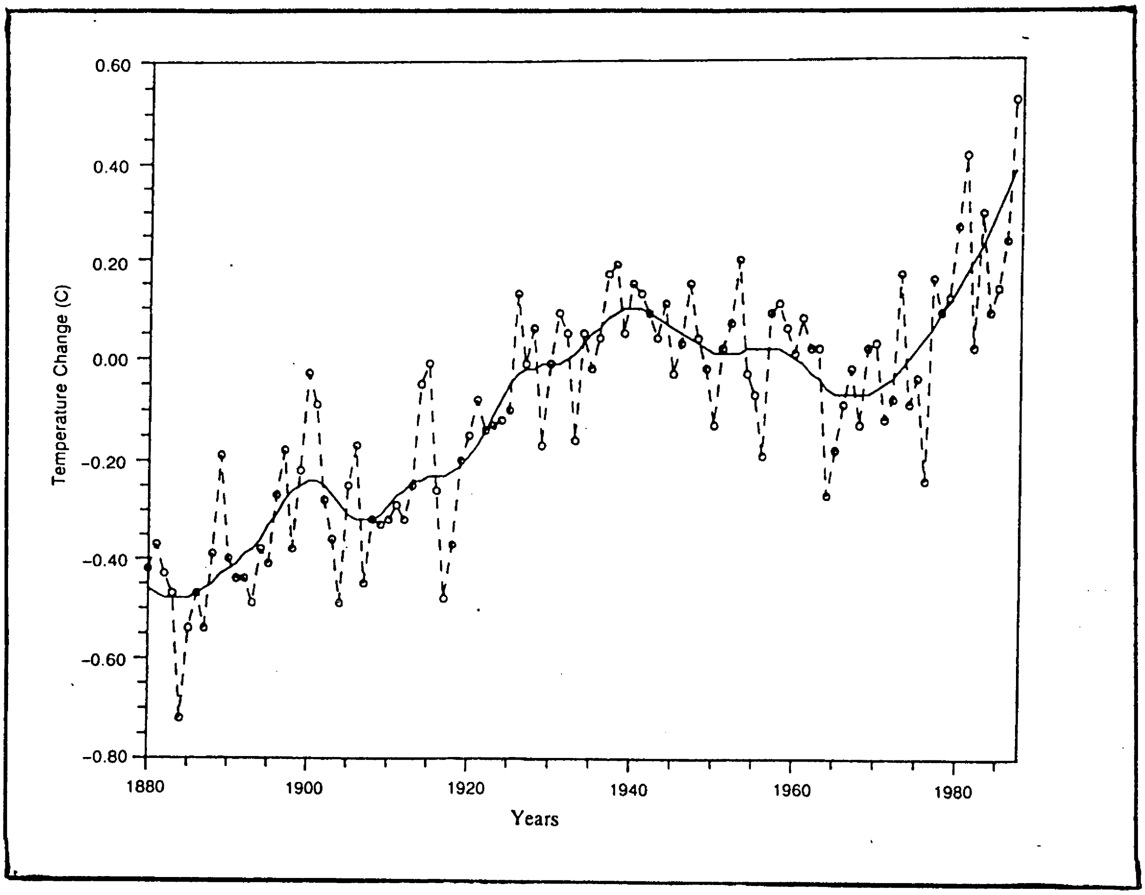
Source: Lashopf and Tirpak 1990, 25

Figure 2.2: **Historic variation of atmospheric carbon dioxide concentration**



Source: MacDonald 1990, 4

Figure 2.3: **The variation of global average temperature from 1880 to 1980 (the solid curve is fitted to a five year moving average)**



Note: Temperature change is the difference between observed temperature and the global average temperature.

Source: MacDonald, 1990, 12

The burning of fossil fuel, changes in land use mainly by converting forest lands to alternative uses, and the production of cement are regarded as the three main anthropogenic activities responsible for the increase in atmospheric CO_2 concentration (MacDonald, 1990, 15). Changes in atmospheric concentration of CO_2 and its effect on trapping radiative flux is well understood, though its effect on feedback processes including the hydrologic cycle and the biosphere is poorly understood. Apparently, there is no agreed threshold level at which the concentration of GHGs becomes critical and causes an abrupt shift in climate (MacDonald, 1990, 90). Because of these uncertainties, there are two extreme groups ranging from the 'sceptics' (who are reluctant to take action) and 'alarmists' (those ready to take immediate action). However, the reality may lie somewhere between these two extremes. Therefore, each country should decide how to respond to climate change in the context of global needs.

2.1.2 Global carbon dioxide emissions and the position of Australia

Table 2.1 shows the major CO_2 emitting countries in the world. USA, former Soviet Union and China are the highest emitters of CO_2 in the world. These three countries rely mostly on coal as their energy source (Coghill, 1990, 78). Australia emits the lowest amount of CO_2 among the industrialised countries. Recent estimates have shown that Australia's contribution is about 1.4 per cent of global GHG emissions (Biomass Taskforce, 1999a). As far as country equity is concerned, Australia is not a significant emitter to abate its CO_2 emissions. However, this country is ranked third among the industrialised countries on per capita emissions. The main energy sources of this country are coal, oil and gas. Its energy consumption has increased by 2.5 per cent per annum over the past 25 years (Biomass Taskforce, 1999a). Consequently, annual CO_2 emission has increased by 8.9 per cent from 385 million tonnes in 1990 to 419 million tonnes in 1996.

As shown in Table 2.2, about one third of Australia's total energy has come from coal, contributing to half of the total CO_2 emissions. Burning fossil fuel is the main cause of CO_2 emissions (Tables 2.2 and 2.4). Predicted CO_2 emissions for Australia in 2010 is shown in Table 2.3. There would be a 70 per cent increase in CO_2 emissions or 193 million tonnes over the values estimated in 1987/8. This, in turn, indicates the need for Government intervention to reduce Australia's increase in GHG emissions. Australia is obliged to reduce its increasing GHG emissions as it is a signatory to the 1992 Framework Convention on Climate Change (FCCC) and the 1997 Kyoto Protocol (CRC, 2000, 1). As shown in Tables 2.2 and 2.3, anticipated increase in CO_2 emissions is mainly caused by increase in coal and oil consumption. Therefore, attention should be given to reducing coal and oil consumption because they are the most important causes of CO_2 emissions in Australia.

Table 2.1: **Major carbon dioxide emitting countries in the world and their contribution to a total of approximately 20 billion tonnes**

Country	Emission %
USA	23
Soviet Union	18
China	9
Germany	6
Japan	4
United Kingdom	3
France	2
Italy	2
Poland	2
Australia	1
All other countries	30
Total	100

Source: Coghill, 1990.

Table 2.2: **Estimated carbon dioxide emissions in Australia during 1987/88**

Energy source	Consumption		Carbon dioxide emissions		Relative emission rate (black coal = 1)
	(PJ)	%	Million t	%	
Coal - black	1395	29	101	38	1.0
- brown	625	13	49	14	1.1
Total coal	2020	42	150	52	
Oil	1635	34	85	34	0.7
Gas	866	18	31	11	0.5
Other	289	6	11	4	
Total	4810	100	277	100	

Sources: 1. Biomass Taskforce, 1999b.

2. Coghill, 1990.

Table 2.3: **Predicted energy consumption and carbon dioxide emissions for Australia in 2010**

Energy source	Consumption		Carbon dioxide emissions		Increase over 1987/8 total emission level	
	(PJ)	%	Million tC	%	Million tC	%
Coal - black	1750	32	185	39	84	31
- brown	800	14	90	19	41	15
Total coal	2550	46	275	58	125	45
Oil	1800	33	130	28	45	16
Gas	900	16	50	11	19	7
Other	250	5	15	3	4	1
Total	5500	100	470	100	193	70

Source: Coghill, 1990.

Table 2.4: **Principal sources of main greenhouse gases**

Greenhouse gas	Main source
Carbon dioxide (CO_2)	fossil fuel burning
Methane (CH_4)	agriculture: rice paddies and ruminants
CFC-12 (representing the CFCs)	man-made: for refrigerants, propellants, foam blowing agents, de-greasing solvents
Nitrous oxide (N_2O)	soils and combustion

Source: Coghil, 1990.

AGO believes that an increase in GHGs in the atmosphere could lead to changes in climate, due to the enhanced natural greenhouse effect causing global warming (AGO, 2000, 14). In Australia, burning of fossil fuel makes a major contribution to the increased CO_2 emissions. The CO_2 emissions of different energy sources are given in Table 2.5. Coal emits the highest amount of CO_2 when compared to all other energy sources. Wood is the lowest CO_2 emitter among the various energy sources, as shown in Table 2.5. The amount of CO_2 emissions from wood is significantly less than coal per MJ energy generated. Therefore, wood can play a role as a sustainable energy source in reducing CO_2 emissions in the future. However, the provisions agreed under the Kyoto Protocol should be considered in utilising wood resources as these resources might be identified as carbon sinks in this Protocol.

Table 2.5: **Emission of CO_2 of the three energy sources**

Energy Source	tC as CO_2 per TJ
Bagasse	109,293
Coal (Australia)	968,860
Wood (generic)	107,777

Source: *Oeko-Institut*, 2000b

2.1.3 Greenhouse gas abatement in Australia and the Kyoto Protocol[1]

The signing of the Kyoto Protocol is an important step that strengthens the international response to climate change by assigning emission targets for developed countries. It focused on sinks that can provide a part of the solution for GHG effect due to growing global fossil fuel consumption. Articles 3.3, 3.4 and 3.7 deal with the inclusion of sinks in the Protocol. Article 3.3 limits present allowable sink activities to afforestation, reforestation and deforestation since 1990. As per this article, net changes in GHG emissions and removals since 1990 will be used to meet commitments to abatement during 2008-12. Therefore, it limits countries' changes in land use during this period as this may affect their commitments to abatement (AGO, 2000, 20-1).

However, Article 3.4 allows countries to apply additional sink activities during the first commitment period (2008-12) if changes in land use lead to increased sequestration. They must be applied during subsequent commitment periods as well. There has been an argument about whether woody weed invasion should be included under these two articles as it provides additional sink activity. If woody weed invasion is included in the Kyoto Protocol, it would create undesirable effects in Australia. If so, it would limit Australia's ability to maintain and to improve the conditions of its ecological resources and sustain productive agriculture in areas having noxious woody weeds. Also it prevents the conversion of lands infested with noxious woody weeds such as camphor laurel, other than by compromising Australia's GHG abatement targets (AGO, 2000, 9).

Article 3.7 allows countries to calculate their assigned amount of abatement based on 1990s net source of GHG emissions of land use change and forestry (AGO, 2000, 20).

[1] The USA's move to undermine the Kyoto Protocol at the Bonn meeting has made Australia's position uncertain. Australia requires the participation of USA and developing countries to ratify this treaty (Kelly, 2001, 26).

The Kyoto Protocol has focused on reducing CO_2 emissions as they contribute to about half of the global warming effect. However, according to Reilly *et al.* (1999), multi-gas control strategies have proved to be reducing costs considerably in abatement processes compared to carbon dioxide-only strategies. It has also been shown that focusing on global warming potential (GWP) of GHGs leads to more mitigation of climate change in multi-gas strategies (Reilly *et al.*, 1999).

GWP is a useful tool in GHG mitigation as this index can be used to estimate relative radiative effect of the various GHGs. For example, this index can be used to estimate the effect of a given reduction in CO_2 emissions compared with a given reduction in any other GHG (WMO and UNEP, 1995, 73). Therefore, this technique can be used to assess the cumulative effect of changes of GHGs by mitigation alternatives. However, according to WMO and UNEP (1995, 73), there is an uncertainty of ± 35 per cent relative to the CO_2 reference at the global level. This uncertainty can be addressed in the evaluation of mitigation alternatives at the regional level as well to obtain better results. Also, the indirect cooling effect of some of the GHGs such as chloroflurocarbons and NO_x can be taken into account in calculating GWPs as these effects tend to reduce the net GWPs of these gases (WMO and UNEP, 1995, 73). Therefore, GWP would be a useful index to compare alternative energy sources for fossil fuel.

2.2. Biomass energy and carbon emissions

Bioenergy is more effective in reducing atmospheric CO_2 than sequestering carbon in trees (Hall *et al.*, 1991, 11). This alternative energy source can be used to produce convenient energy carriers such as electricity, gases and transportation fuels (Hall, 1997, 17).

2.2.1 Potential of biomass as an energy source

Biomass has been widely recognised as a potential sustainable energy source with considerable benefits especially in its ability to reduce CO_2 emissions. The current consumption of biomass energy is 14 per cent of the global primary energy use (Leeman *et al.*, 1996). According to IEA (2000), it is cost effective and has the potential of meeting 50 per cent of world energy demand in the future (IEA, 2000). Considering these reasons, IEA formed an international collaboration called IEA Bioenergy. This was set up in 1978 with the objective of improving international cooperation and exchange of information between national bioenergy research and development programs. Australia is one of the member countries that has signed this agreement, which is implemented through a series of tasks (IEA, 2000).

At present, in Australia about five per cent of energy comes from biomass (Biomass Taskforce, 1999a). Use of agricultural crop residues such as bagasse and cane trash from sugarcane industry, straw and stubble from cereal cropping, cotton-gin residues from the cotton growing industry and rice hulls are identified as potential bioenergy sources. Among these resources, residues from the sugarcane industry are believed to have the greatest potential because the economic feasibility of using straw and stubble from cereal cropping and rice hulls is uncertain due to high costs of collection and transport. Cotton-gin residues have the potential to generate electricity only on a small scale (Biomass Taskforce, 1999b).

2.2.2 Potential of residues from sugar cane industry as a bioenergy source

The sugar cane industry in Australia is largely located between Lismore (NSW) and Cairns (Queensland) on the eastern seaboard. There are 28 sugar mills operating in the area. Bagasse is used as the main energy source especially during the harvesting and crushing season (June to November) to generate energy for processing machines, processing heat and electricity. Bagasse, the residual fibre from raw sugar processing, currently provides about 90 PJ or about two per cent of the country's total primary energy demand. During the off-season fossil fuel is used by these sugar mills (Biomass Taskforce, 1999b).

At present, only 50 per cent of the cane biomass is used to produce energy. However, there is potential for increasing renewable energy generation from cane trash and bagasse in future by development of technology and using alternative fuels during the off-season (Biomass Taskforce 1999b). As per recent estimates, this industry could be developed to produce 3400 MWh of electricity (20,722 GWh per annum). This, in turn, could reduce Australia's CO_2 emissions by 16.5 million tonnes per annum. Therefore, there is potential to meet additional two per cent renewable energy target from this industry with its full development as sugar cane is one of the least expensive bioenergy source in Australia (Biomass Taskforce, 1999b). In Brazil, residues from the sugar industry significantly contribute to reduce GHG emissions when substituted for fossil fuel (Macedo, 1992, 77)

2.2.3 Bioenergy in the context of Australia's National Greenhouse Strategy

As a requirement of the Kyoto Protocol Australia needs to limit its net GHG emissions to 108 per cent of 1990 levels by the end of the first commitment period (2008-12) (AGO, 2000, 2). But it has been estimated that the country's net emissions would increase by 43 per cent above 1990 levels by 2010 (Biomass Taskforce, 1999b). Therefore, Australia has focused on renewable fuels including biomass to reduce GHG emissions. The activities proposed for utilisation of biomass for bioenergy are (Biomass Taskforce, 1999a);

(I) harvesting environmental weeds such as camphor laurel (*Cinnamomum camphora*) and *Mimosa pigra* for bioenergy, and the use of forest biomass to generate electricity for sugar mills;

(II) utilisation of oil mallee, which has been grown to mitigate soil salinity in integrated processing plants;

(III) use of wood waste for bioenergy;

(IV) improving the use of sugarcane trash and bagasse as bioenergy in sugar mills (Biomass Taskforce, 1999b).

The Federal Government of Australia has set a target of increasing renewable energy supply by 9,500 GWh per annum by 2010 through an increase in renewable electricity contribution from 10.5 per cent in 1996/7 to 12.5 per cent by 2010 (Biomass Taskforce, 1999a). The government has focused on biomass by-products of agriculture and forestry, biomass by-products of food processing and production industries and biomass component of mixed municipal wastes to achieve this target. If supplemented with alternative biomass and technical development, residues of the sugar cane industry alone have the potential to meet this target because of their low cost and great potential for power generation required by sugar mills (Biomass Taskforce, 1999b).

Therefore, it is important to examine the feasibility of using the proposed bioenergy sources such as camphor laurel (*Cinnamomum camphora*) as supplementary bioenergy sources for sugar mills and to supply energy to the grid, as they could play a great role in achieving the Government's renewable energy target. This is worthy of consideration because studies conducted by Tahara *et. al.* (1999, 1183) have shown that power generation with a sustainable forestry system emits less CO_2 emissions than those generating power from fossil fuel.

2.2.4 Camphor laurel (*Cinnamomum camphora*) in Australia

As outlined in Chapter 1, camphor laurel is identified as a weed in northern NSW, where this species is abundant. However, this species can be viewed as a resource that can be developed to derive commercial benefits rather than merely considering it as noxious weed (Stubbs and Cameron, 1999, 11). Past evidence shows that there is potential for using this resource as a timber source. For example, camphor wood has been used in China, Japan, India and in Western countries for making high quality artefacts, valuable furniture, and cupboards (Stubbs and Cameron, 1999, 11). Also, there is evidence of local commercial use of this species as timber before 1950s in Grafton (Stubbs and Cameron, 1999, 12).

However, use of this species commercially as a bioenergy source is novel. There is hardly any evidence in the literature on the commercial use of this species for bioenergy (Stubbs and Cameron, 1999, 11). On the other hand, Kooyman (2000, 6) has shown that replacing this weed with local species could cause both positive and negative effects on existing threatened species. Therefore, pre-harvest surveys and stand assessment should be done to adopt appropriate measures to avoid negative effects on the existing threatened species (Kooyman, 2000, 8). Also, studies on the feasibility of using this resource as a bioenergy source to supplement sugar cane industry are important to SFNSW in implementing the proposed harvest-reforestation project.

2.2.5 Evaluation of greenhouse gas emissions from bioenergy sources

Land plays an important role in the production of bioenergy. Though bioenergy has been identified as a significant energy source in future climate change abatement attempts, severe limitations have been observed in global bioenergy supply due to the unavailability of suitable land. Limitations arise mainly due to the possible consequences of other land uses such as deforestation and its impact on biodiversity (Leeman *et al.*, 1996, 3). Therefore, any environmental assessment of bioenergy systems needs to integrate land use because land required to produce energy crops has alternative uses. The technique called Life Cycle Assessment (LCA) can be applied to the evaluation of social and environmental pros and cons of bioenergy systems and in determining external costs (Hall and Scrase, 1998, 357).

LCA is a technique that can be used to assess the impacts of a product or process on the environment. It is called a "cradle to grave approach" as it can include all the direct and the indirect effects beginning with the production of raw materials up to the end use of the product (Audsley, 1997). This technique can be applied to environmental problems of CO_2 emissions (Amato *et al.*, 1996, 235). However, the accuracy of results of life cycle assessment depends on a correct definition of the reference system. Different reference system alternatives for the same LCA objective, different geographical boundaries and different combinations of land use producing the same uses would give different quantitative results (Jungk *et al.*, 2000).

Therefore, geographic boundaries must be carefully defined while giving attention to issues such as time interval analysed and changes of carbon stocks, reference energy systems, energy inputs required, process and transport fuels, energy losses along the entire fuel chain, energy embodied in infrastructure, distribution systems, cogeneration systems, by-products, waste wood and other biomass waste for energy, reference land use and other environmental issues. According to Schilamadinger *et al.* (1997, 359) acidifying emissions (SO_2, NO_x), particulate emissions, effects on water quality and biodiversity should also be considered in assessing the environmental acceptability of bioenergy. In addition, bioenergy can be either a by-product or a main product in a project. Emissions associated with both products should be included in the assessment.

In the analysis of bioenergy projects, both the reduction of carbon emissions from fossil fuels and the influence of biomass harvest on dependent carbon pool sizes and carbon fluxes must be taken into account in estimating the net reduction of emissions (Schilamadinger *et al.*, 1997, 359). Trade-offs between maximum biomass harvest and maximum biomass storage must be considered in bioenergy projects if there exist afforestation measures that may compete for land opportunities (Harmon *et al.*, 1990). In this sort of project, debris left over on the ground after extracting harvested biomass and the biomass stored in below-ground parts should also be considered in evaluating GHG emissions (Turner *et al.*, 1999, 13).

2.2.6 Emissions from residues after clearing and extraction

Clearing, which is often followed by burning, immediately releases GHGs while below-ground parts decompose and then slowly release GHGs (Turner, *et al.*, 1999, 13). The main process in the decomposition is respirational loss of organically bound carbon. During the decomposition process, microbes transform this carbon into CO_2 through respiration (Mackensen *et al.*, 1999, 2). Inclusion of the emissions from residues from clearing is important. Graetz (1998) has estimated that the contribution of these residual parts to the total emissions was 40 per cent over the period 1981-1990 in Australia.

However, current information on the proportion of total biomass stored in these residues and emissions associated with them is lacking and, therefore, further research is required to improve the quality of GHG analyses (Eamus *et al.*, 2000, 14). The proportion of total biomass stored in these residues is important in estimating GHG emissions, because these parts emit significant emissions. The proportions of total biomass stored in left-over parts from clearing depend on the type of vegetation, climate and clearing method (Eamus *et al.*, 2000, 14).

It has been estimated that the proportion of biomass stored in the below ground alone ranges from 3-49 per cent of total biomass for tropical and subtropical forests, with a range in root mass of 11-130 tonnes per hectare (Brown, 1997, 134). Decaying time period of these parts is also important in GHG emissions analysis as remaining parts with pure carbon slowly decay and release CO_2 to the atmosphere. Decaying rate and time period depend on the type of vegetation, wood properties, climate and nature of decay organisms (Turner *et al.*, 1999, 13). It may take even 50 years from these residual parts clearing to decay. However, the contribution to total emissions could be insignificant after 10 years provided the decay function is a negative exponential function (Turner *et al.*, 1999, 13).

2.2.7 Software for the life cycle analysis of bioenergy or biofuel projects

Various computer-based models are available for the assessment of GHG emissions of various energy systems. The following models are important for the assessment of GHG emissions of bioenergy projects (IEA, 2000).

(I) GORCAM - Graz/Oak Ridge Carbon Accounting Model

(II) GEMIS - Global Emission Model for Integrated Systems

GORCAM - Graz/Oak Ridge Carbon Accounting Model

GORCAM is an Excel spread sheet model developed for the calculation of net carbon changes in the atmosphere due to land use, changes in land use, bioenergy and forestry projects (Schilamadinger *et al.*, 2000). This model takes into account fluxes and changes of carbon stored in vegetation, plant litter and soil, reduction of carbon emissions due to replacement of fossil fuels by biofuels, carbon storage in wood products, decrease in carbon emissions due to use of timber products instead of energy-intensive materials such as steel or concrete, burning of by-products of timber, fossil fuels used to produce biofuels and wood products. It also can model multiple thinnings when the ratio of product distribution is constant. Users should have experience in Visual Basic software to identify exactly what data and what equations are used in the model (Schilamadinger *et al.*, 2000). However, benefits and costs cannot be incorporated in GORCAM in the analysis of alternative energy sources.

GEMIS - Global Emission Model for Integrated Systems

GEMIS was developed by *Oeko-Institut* and *Gesamthochschule Kassel* (GhK) in 1987-1989. It is an upgraded and updated sophisticated life cycle analysis model, database and cost-emission analysis system (*Oeko-Institut*, 2000b). GEMIS database consists of information on (*Oeko-Institut*, 2000b):

(I) fossil fuel (hard coal, lignite, natural gas and oil), renewable, nuclear, biomass (residuals, wood from short rotation forestry, miscanthus, rape oil and so on) and hydrogen;

(II) processes for electricity and heat (power plants, cogenerators, and fuel cells);

(III) Raw and base materials; and

(IV) all means of transport using diesel, gasoline, electricity and biofuels.

GEMIS can take into account chosen system boundaries and deviations from multi-objectives, such as costs versus emissions or costs versus land use, and so on (*Oeko-Institut*, 2000a). Therefore, this package is more appropriate than GORCAM if costs are included in the analysis. However, it is not designed to compare the benefits with costs of alternative energy sources. Hence, a separate economic analysis is needed to evaluate the economic feasibility of alternative energy sources when GEMIS is used to evaluate greenhouse gas emissions of alternative energy sources.

2.3 Control of camphor laurel

Various avenues of carbon emissions and abatement under two alternatives for the control of camphor laurel outlined in Chapter 1, are shown in Figure 2.4. In the deferring action, camphor estate acts as a carbon sink that sequesters atmospheric CO_2 while landowners continue to incur income losses. Also, the two sugar mills continue to use coal with bagasse to generate energy and emit GHGs. As discussed in Chapter 1, the project put forward by SFNSW aims at developing a sustainable timber industry by converting this camphor estate to eucalypt plantations. Eucalypts sequester CO_2 and store carbon. Timber from camphor and eucalypts act as carbon storage. Also, in the mitigation scenario, the two sugar mills utilise bioenergy from camphor and eucalypts and emit GHGs. The issue is, which of the two alternatives is economically feasible and at the same time capable of emitting less GHGs while storing more carbon.

2.3.1 Comparison of greenhouse gas emissions

As outlined earlier, SFNSW has indicated that the project emits less carbon than the deferring action does. However, SFNSW has not taken into account other GHGs such as N_2O and CH_4 in estimating GHG benefits of the project. As other GHGs are significant in the greenhouse effect, an estimation of the overall effect of all the relevant GHGs is necessary and this would address the possible concerns of the AGO. The LCA framework used for the estimation of these GHGs is depicted in Figure 2.5. Since both alternative actions use bagasse, the sugarcane bioenergy system is taken as common for both actions for LCA. The relevant processes taken for the estimation of GHGs under a fossil energy system, sugarcane and camphor-eucalypt bioenergy systems are shown in this framework.

Figure 2.4: **Avenues of carbon emissions and abatement under the two alternative actions**

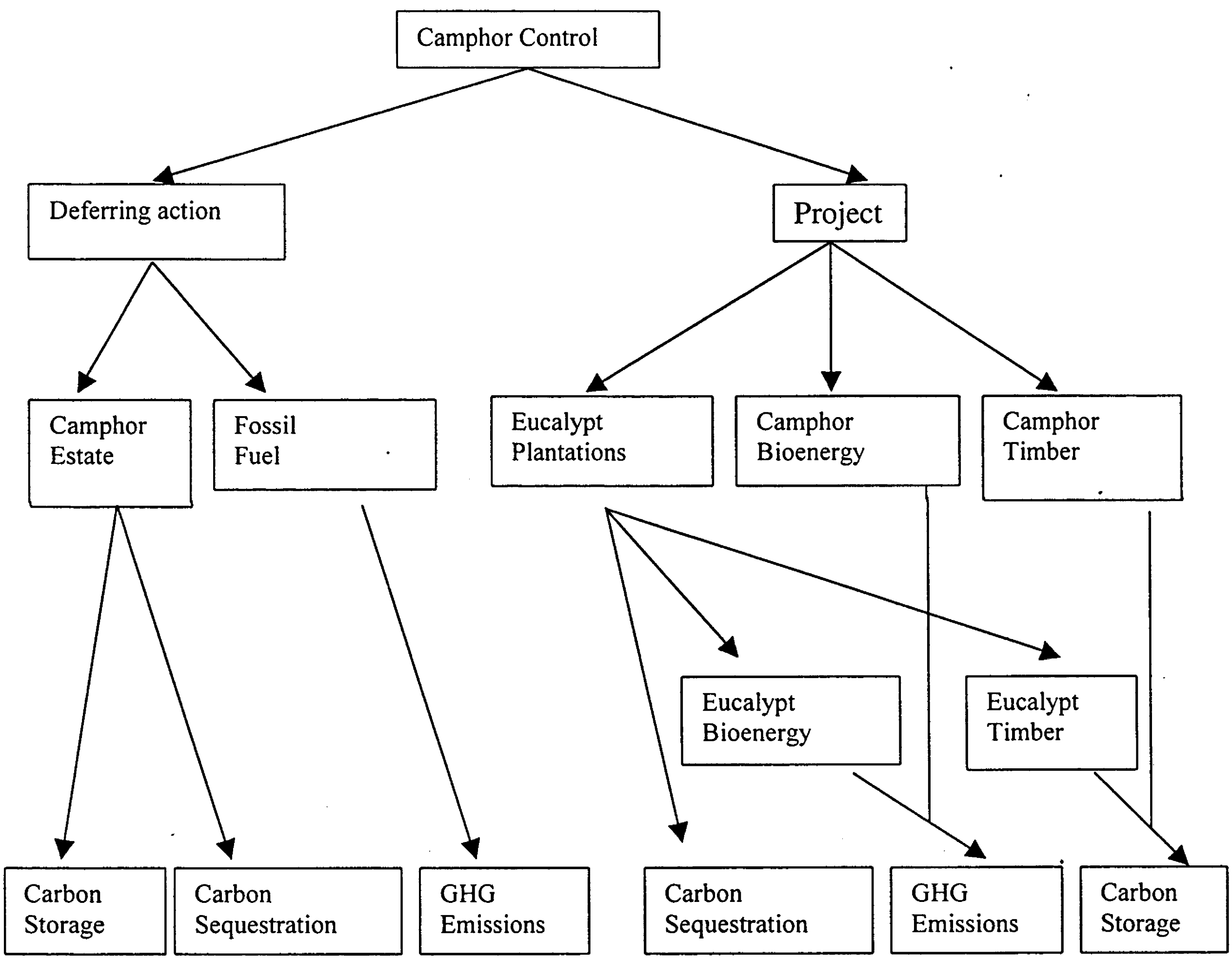
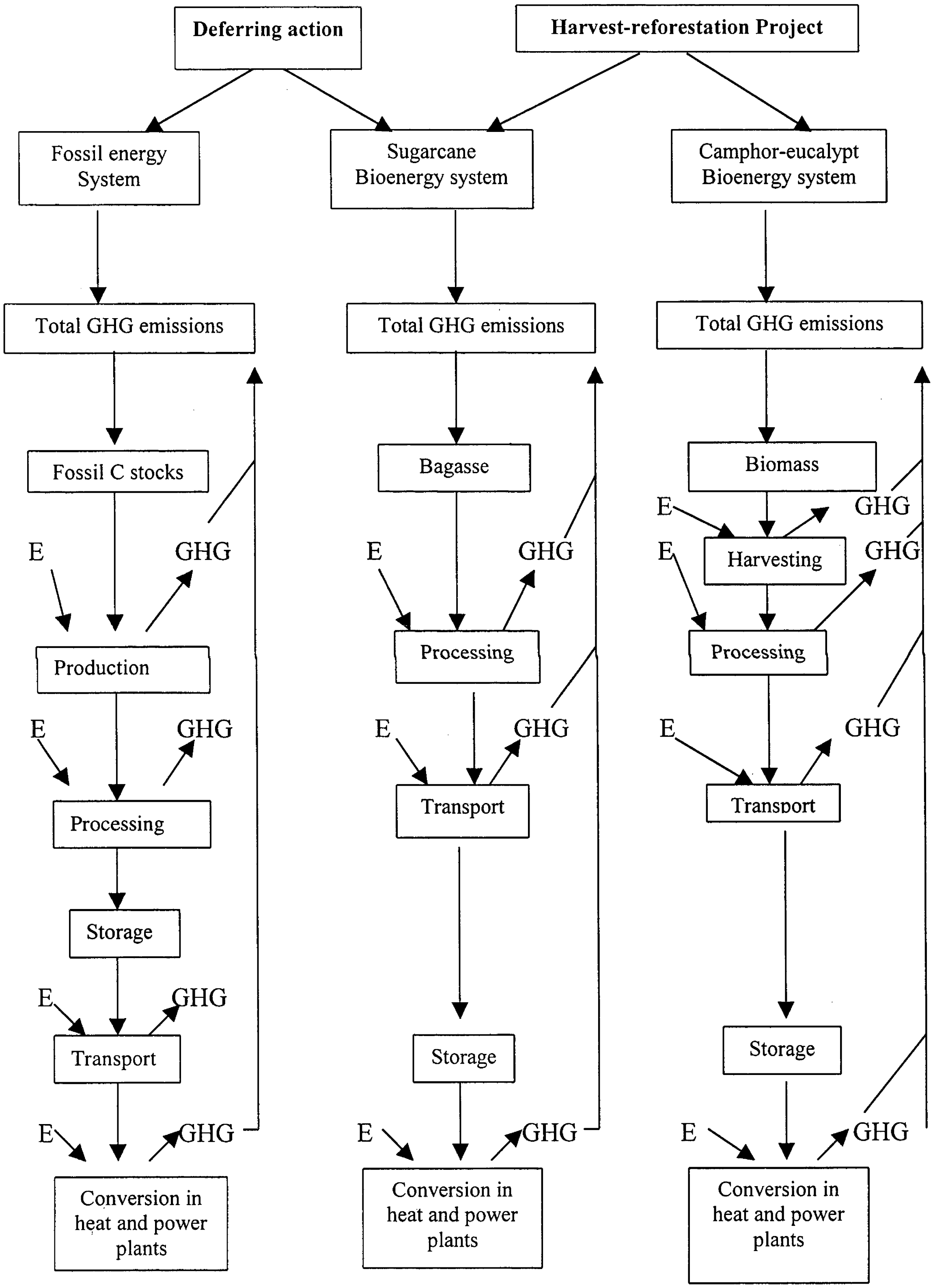


Figure 2.5: **Conceptual framework for the comparison of greenhouse gas emissions of the two alternatives**



2.3.2 Comparison of carbon sink

In the baseline scenario, there is a considerable amount of carbon stored in camphor laurel. Although this stored carbon is removed in the mitigation scenario, carbon accumulates in these timber products in future as eucalypt and camphor timber products for construction and furniture can store carbon for more than 75 years (SFNSW 2000: 2). Timber products can store 30-40 per cent of carbon stored on land (Dewar and Cannell, 1990, 49). However, the amount of carbon stored in timber products depends on their life span (Sathaye and Meyers, 1995, 25). As shown in the *Land Use Change and Forestry Workbook*, carbon stored in timber used for house construction and furniture in Australia could last for 90 years (AGO, 1999, 17). However, investigation of the long term accumulation of stored carbon in these products is beyond the scope of this study.

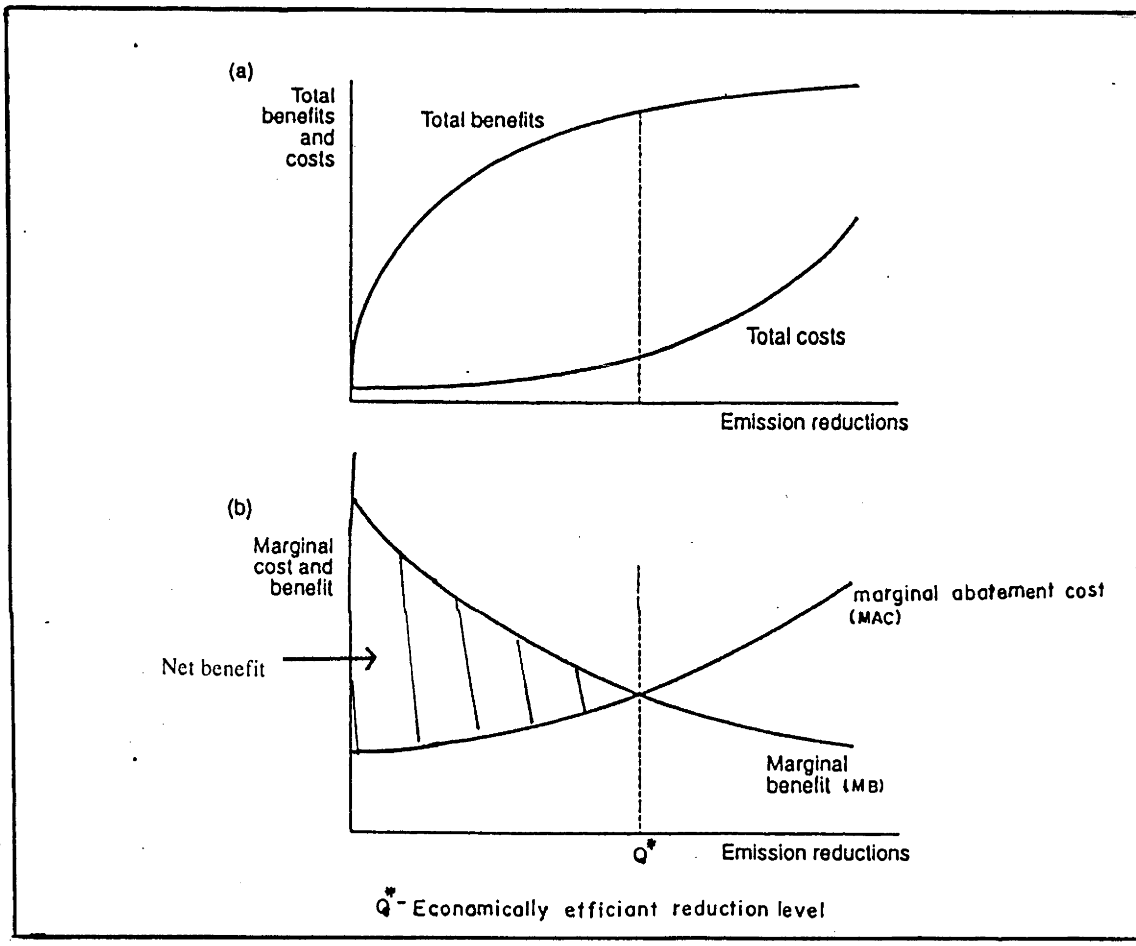
2.4 Economics of carbon dioxide emissions abatement

In addition to the assessment of GHGs, economic assessment of the two alternatives is important in assessing the worth of the project. The results of the preliminary investigation suggest that it is necessary to carry out a detailed economic analysis to justify the investment. There are two kinds of project appraisal, namely, financial analysis and economic analysis. Financial analysis is conducted from the point of view of a private investor to find out whether sufficient finances can be raised in market to undertake a project, whereas economic analysis takes into account the public, and hence, the welfare of the whole society. This study focuses only on economic analysis rather than a financial analysis. Economic analysis is more relevant to this case as GHG mitigation is a public good.

Economic efficiency that can be adopted as a criterion for assessing CO_2 emission abatement strategies. Economically efficient emission reduction maximises environmental benefits. Figure 2.6 shows how the economically efficient solution occurs in GHG abatement. Total benefits and total cost curves are shown in Figure 2.6(a). As emission control increases, total benefits, as well as total costs, increase. The benefits of an additional unit of reduction of emission, called marginal benefits (MB) and the cost of an extra unit of reduction of emissions, called marginal abatement cost

(MAC), are shown in Table 2.6(b). As depicted in Figure 2.6(b), economically efficient abatement occurs when MB of reduced global warming equal MAC (GEF, 1992, 5-7). It is economically inefficient to reduce emission beyond this abatement level as MAC is higher than MB.

Figure 2.6: **Total benefits and total costs and marginal benefits and marginal costs of emission abatement**



Source: GEF, 1992, 6

2.4.1 Economic assessment of forestry related greenhouse gas abatement projects

From society's point of view, environmental programs are feasible when resources spent on these programs give more benefits from the cleaner environment than the cost of abatement. Therefore, comparison of benefits and costs is the best way to determine the economic feasibility of any specific environmental program. Cost-benefit analysis (CBA) is the preferred analytical tool in the literature for this comparison and decision-making (Palmer *et al.*, 1995, 131). However, practical application of CBA is difficult due to the global and intergenerational nature of the problem, and difficulties in estimating marginal damage costs of climate change (Bruce *et al.*, 1996, 1). Decision makers face the following central questions in GHG emissions abatement process (Bruce *et al.*, 1996, 150).

(I) How much of greenhouse gas emissions should be reduced?

(II) When should emissions be reduced?

(III) How should emissions be reduced?

(IV) Who should reduce emissions?

CBA can be used to answer the first three questions. However, the fourth question is an equity problem that cannot be solved by using CBA. Also, traditional CBA cannot be used to obtain answers for the first three questions because it takes into account only direct costs and direct benefits (Bruce *et al.*, 1996, 151). The following techniques in modern CBA can be used for practical policy making: Cost effectiveness analysis; Multicriteria analysis; and Decision analysis.

Cost-effectiveness analysis can be used to find the most effective or least-cost option to meet the desirable level of benefits. The advantage of this technique is that it does not require the benefits be valued explicitly. This technique has the most widespread application to the problem of climate change to identify the least-cost alternative to achieve a given level of GHG abatement (Bruce *et al.*, 1996, 151). Multicriteria analysis is designed to deal with multiple objectives. It allows trade-offs between conflicting objectives. This approach can be used when it is difficult to assign values to all the costs and benefits of a project. For example, it is difficult to assign a value to loss of biodiversity. Since economic analysis of climate change mitigation projects faces similar problems, this technique can be applied for such situations (Bruce *et al.*, 1996, 151). Decision analysis is a further extension of CBA that allows decisions to be taken under conditions of uncertainty. It is a useful technique for the climate change problem as it can deal with the problem of uncertainty (Bruce *et al.*, 1996, 151). Also, this technique can be used to address the problem of irreversibility by incorporating costs of irreversible effects in the analysis (Bruce *et al.*, 1996, 160).

The following major uncertainties should be considered in the evaluation of climate change mitigation alternatives (Bruce *et al.*, 1996, 161).

(I) Uncertainty about future rates of emissions.

Level of uncertainty increases when CO_2 emissions from fossil fuel use and deforestation in the more distant future are considered.

(II) Uncertainty about scientific linkages.

Scientific linkages between global warming and GHG emissions are not well established. Also, there is an uncertainty of establishing these linkages in future research.

(III) Uncertainty in valuing the costs and benefits.

Large variations in uncertainty occur in valuing costs and benefits of mitigation measures. For example, the level of uncertainty of estimating the cost of protective dykes to protect land from sea level rise is significantly less than estimating the impacts on biodiversity.

(V) Uncertainty about the joint benefits and costs.

There are joint benefits and costs in climate change abatement. For instance, measures to mitigate CO_2 emissions are often linked with the abatement of other pollutants such as SO_2 and particulates (GEF, 1992, 5). Though these joint benefits and costs are subject to uncertainties, they may be a significant factor in the evaluation of abatement options.

2.4.2 Assessment of the benefits and costs

Estimation of the opportunity cost of a product or activity is the basis for the estimation of mitigation and adaptation costs. Social costs should be used in the analysis of mitigation options. Social costs could be obtained by correcting market prices. This can be done by correcting market prices for distortions, called shadow prices and correcting prices for both positive and negative external effects (Christensen *et al.*, 1998, 10). The main costs components and benefits of forestry related GHG mitigation projects are listed below (Christensen *et al.*, 1998, 84-5). In addition to the benefits listed below, employment benefits of these mitigation projects should be taken into account in the appraisal. The benefits of employment are equal to the social costs of unemployment avoided as a result of the project. The value of reduced unemployment can be inferred by salaries and wages paid to the workers (Halsnaes *et al.*, 1999, 40).

The main cost components are:

(I) Land rents (market land rent or opportunity cost of the best alternative land use, such as agriculture);

(II) Land conversion costs at the beginning of the project and subsequent regeneration costs after harvesting;

(III) Establishment costs - seeds or seedlings and other material costs, labour costs, infrastructure costs and maintenance and silvicultural costs;

(IV) Harvesting costs;

(V) Overhead costs including depreciation;

(VI) Negative impact on biodiversity.

Benefits are:

(I) Value of timber and non-timber products;

(II) Shadow price of saved GHGs;

(III) Other environmental benefits (biodiversity, watershed protection and so on);

(IV) Recreation benefits.

A broad assessment of benefits and costs of GHG emissions and abatement is possible under a wide range of uncertainties, judgements and assumptions. However, sufficient information is available at this stage to point out at least the relative magnitudes of benefits and costs. These relative magnitudes of benefits and costs are useful to show the areas where efforts and investment are necessary (National Landcare Program, 1997, 95).

In case of afforestation projects with bioenergy components, the cost should be expressed in terms of tonne-carbon to compare the costs of carbon storage in forestry components with the costs of other carbon emission reduction measures such as bioenergy. As terrestrial carbon sinks cannot accumulate carbon indefinitely, carbon storage benefit of these sinks can be considered as a one-time increment in the carbon stock (Swisher, 1995, 61; Swisher, 1997, 336). Therefore, benefits and corresponding cost value can be taken as a one-time value rather than annualized values. The benefits of saved GHGs in fossil fuel replaced by bioenergy are also important in assessing the feasibility of this sort of project. The quantity of carbon saved in fossil fuel depends on the type of fossil fuel replaced, the heating value of the bioenergy source and the relative efficiencies of biomass and fossil fuel combustion (including losses in transport) and the carbon embodied in fossil fuel used to produce bioenergy(Swisher 1993; Turhollow and Perlack 1991, 129).

Opportunity cost includes the costs of development and operation of the project as well as the opportunity cost of land is important related bioenergy projects. There are various approaches used in estimating the opportunity cost of land. Land rent, land market price and net benefits of the best alternative land use could be used to estimate opportunity cost (Sathaye and Meyers, 1995, 11). Opportunity cost can also be calculated by taking the difference between land value with and without the project. However, the values of marketable outputs and carbon savings must be subtracted from the opportunity cost (Swisher, 1991, 319). Also, these projects should take into account time profile, cost efficiency and transaction costs for an adequate appraisal (Bohlin and Eriksson, 1996, 1223).

2.4.3 Criteria for benefit cost analysis

The following criteria can be applied for the evaluation of benefits in comparison to costs of forestry related GHG mitigation projects (Sathaye and Meyers, 1995, 12).

(I) Initial cost per hectare and per tonne of carbon

(II) Endowment requirements per hectare and per tonne of carbon

(III) Net present value (NPV) per hectare and per tonne of carbon

(V) Benefit of reducing atmospheric carbon (BRAC)

Initial cost per hectare and per tonne of carbon takes into account only the initial resources to establish a project. This criterion gives valuable information on the amount of resources required to start a project. However, this criterion does not include future investments during the project period. The criterion, endowment requirements, includes both establishment costs and all discounted future costs and recurring costs of projects. This criterion is useful to evaluate the endowment required to maintain projects, which do not give substantial monetary benefits. Net direct benefits of a project can be obtained by applying the criterion called NPV. The advantage of NPV is that both direct and indirect costs and benefits can be included in this technique. BRAC can capture the lifetime of carbon in the atmosphere. Hence, this indicator provides time-dependent economic analysis of atmospheric carbon mitigation projects (Sathaye and Meyers, 1995, 12-13). In this study NPV has been used.

2.4.4 Externalities

The main economic problem of fossil fuel burning and changes in land use (mainly deforestation) is the external effects on the environment due to GHG emissions. This externality can lead to loss of social welfare. These external effects are said to be internalised if loss of welfare is compensated by the agent causing the externality (Pearce and Turner, 1990, 61). The decision makers in government would be able to take into account the full social values of inputs and outputs at the socially optimal level once these external effects are internalised in prices. The benefits of a reduction of GHGs depend on the valuations given to reduction of emissions. These valuations depend on the following factors (National Landcare Program, 1997, 95).

(I) the understanding of possible effects of GHG emissions on global warming;
(II) the risk of under-estimating the effects of GHG emissions on global warming;
(III) an understanding of the urgency of achieving reductions;
(IV) commitments and policies of the national government; and
(V) the costs of achieving commitments and policy goals.

The precision of valuations of GHG emissions depends on the international tendency to mitigate the emissions and the ability to establish definite assessment of the scale of global warming (National Landcare Program, 1997, 95).

2.4.5 Valuation of externalities: Greenhouse gas emissions and sequestration benefits in Australia

There exist estimates of these values related to Australia. For example, ABARE (1994, 9) has calculated likely reductions in GHG emissions from the agriculture sector in Australia on the basis of imposition of a tax on GHG emissions from this sector. The tax on these emissions has been derived through estimation of a shadow price of GHG emission reduction. According to these calculations, the estimated marginal cost ranges from \$20 to \$30 per tonne of GHGs in CO_2 equivalents for a 20 to 30 per cent reduction in total GHG emissions from the agriculture sector (ABARE, 1994, 9).

In contrast, the Industry Commission (1991, reported in ABARE, 1994, 9) has estimated that the emission tax necessary to achieve the reduction target of the whole economy was about \$27 per tonne in CO_2 equivalents in 1991-92 dollars. It has been shown in ABARE (1994, 9) that this value would be equivalent to \$21.75 per tonne in CO_2 equivalents in 1998 dollars and a 30 per cent emission reduction could be achieved in the agriculture sector at this tax rate. This estimated tax rate in 1998 dollars could be used in valuing GHG emissions and sequestration benefits in Australia as it represents the whole economy.

2.4.6 Discount rate

The discount rate is an important factor in the evaluation of mitigation alternatives. It is subject to debate among economists because benefits and costs occurring in the future are worth less to society than those are in the present. Therefore, different discount rates are used in different situations (Davison and Freund, 1999, 695). Table 2.6 shows the sector specific discount rates used in simulation studies in Australia. A given target with reduced cost of abatement could be obtained by using a discount rate of 10 per cent that could induce consumers and investors (ABARE, 1991, 33).

It is often argued that long-term environmental projects must use lower social discount rates of the order of 2 per cent (Cline, 1992, 54). This study will examine the sensitivity of the results to discount rate.

Table 2.6: **Discount rates used in climate change mitigation studies in Australia**

Sector	Discount rate (%)
Government owned electricity utilities; cogeneration plant	10
Processes (including oil refineries and natural gas pipelines)	15
Energy-using companies (for industrial demand devices)	25
Private individual consumers (residential sector)	50
Transport (for motor vehicles)	25

Source: ABARE, 1991.

The next chapter outlines the techniques used in the evaluation of GHG emissions under the two alternative actions discussed in this chapter.

3. Chapter 3. Evaluation Methodology

The techniques necessary for the evaluation of GHG emissions under the two alternative scenarios associated with the project are discussed in this Chapter. The Chapter is divided into two main sections. The technique called LCA, adopted to estimate GHG emissions of the two alternatives, is discussed in Section 3.1 while the approach used to assess the economics of the project is discussed in Section 3.2.

3.1 Evaluation of greenhouse gas emissions

This study focuses on estimating the emissions of GHGs such as CO_2, CH_4 and N_2O in all the steps in the production of electricity using the three main energy sources, namely fossil fuel (coal), sugar cane trash and bagasse, and camphor biomass. It also examines how GHG emissions of different combinations of these energy sources compare with the estimated carbon benefits of the project. The LCA was used to estimate the GHG emission levels with and without the project by comparing greenhouse gas emission levels of current energy sources such as bagasse and fossil fuel with the emission level from proposed camphor bioenergy. The GEMIS software package was used for this comparison. The features of this software package are outlined in Chapter 2. Considering the time and cost, and the commercial confidentiality in relation to data in the industry, the secondary data available in the product and process database of this software was used for this study. GHG emission levels under the following two scenarios were examined using this software.

(I) The baseline scenario without the project.

(II) The mitigation scenario:

The details of each scenario are described below.

3.1.1 The baseline scenario

The baseline scenario that is to be compared with the project encapsulates the existing camphor laurel vegetation which is under natural spreading and two sugar mills in the region with an established pattern of energy use including fossil fuel. As stated in Chapter 1, the two sugar mills use fossil fuel and bagasse in combination as energy sources and operate only during cane harvesting and crushing season from June to November. The actual contribution of these two fuel sources in their energy generation process in these mills was not available for this study due to commercial confidentiality. Therefore, the potential GHG emissions of different combinations of these two energy sources in the energy generation process under this project specific baseline were considered as the benchmarks. The various combinations of fossil fuel and bagasse chosen for examination are shown in Table 3.1. Australian coal was treated as the fossil fuel used to generate energy, specifically electrical energy.

Table 3.1: **The different combinations of energy from fossil fuel and bagasse used under the baseline scenario**

Benchmark No.	Amount of energy from coal (%)	Amount of energy from bagasse (%)
1	10	90
2	20	80
3	30	70
4	40	60
5	50	50

The benchmark ratios were assumed to remain unchanged during the project period for ease of comparison. The following assumptions were made under the baseline scenario.

(a) The two sugar mills continue using only fossil fuel and bagasse as energy sources;

(b) The cultivation area of sugarcane remains the same during the project period and there is constant supply of bagasse for energy generation;

(c) Sugarcane trash is burnt in the field as practised in the past and is not used to generate energy during the project period;

(d) There is no technological improvement in energy use of the two sugar mills during the project period; and

(e) Camphor laurel vegetation in Tweed and Byron Shires continues to spread without control during the project period.

3.1.2. The mitigation scenario

A harvest-reforestation project is central to this GHG mitigation. In this scenario camphor and eucalypt biomass are introduced as alternative energy sources to fossil fuel to supplement bagasse in energy generation at the two sugar mills. As data on emissions of camphor burning could not be found, the emissions data for generic wood available in the GEMIS database was used in the analysis. Among the two available residues of the sugar industry, namely sugar cane trash and bagasse, the two sugar mills currently utilise only bagasse as an energy source. These mills plan to utilise in future sugarcane trash as well in generating energy with the project. Therefore, the emissions from both of these by-products should be included in the analysis. However, the emissions from sugarcane trash were not included in the analysis because the emissions data pertaining to this by-product was not available in the product database of GEMIS.

The following assumptions were made in this scenario:

(a) The emissions data for fuel wood available in the database was a reasonable approximation for the emissions from camphor wood;

(b) The exclusion of GHG emissions of sugarcane trash in this scenario would not make a significant difference to the final outcome as this component is common to the two scenarios;

(c) The technical upgrade to the boiler capacity done to incorporate camphor biomass in the energy generation process and this upgraded technology remain unchanged during the project period.

3.1.3 Reference area

The LCA takes into account all the GHG emissions from the production of raw material up to the end use of the product. As a result, the reference area can be different from the case study area. The reference area in the present study crosses geographic boundaries of the country. However, a considerable amount of GHGs is emitted in Tweed and Byron Shires because both scenarios include the inputs other than fossil fuel, and outputs of energy generation in this region. For instance, bagasse and sugar cane trash come from the sugar industry in this region. Similarly, the concern of camphor infested land is specific to this region.

There is no need to grow camphor elsewhere, because this species is a noxious weed that needs to be eradicated from this region. Hence, for the purpose of LCA, it is not required to find land outside this region or the country to grow this vegetation that is cleared by the project. Also, the generated energy is used within this region. Therefore, GHG emissions from all other parts of the lifecycle such as production of fossil fuel and the manufacturing of machinery and equipment can be considered as a minor component. Considering these reasons, the reference area was chosen as Tweed and Byron Shires for this study.

3.1.4 System description

The energy systems of the two scenarios are shown in Figure 1.6. The details of the inputs and the energy production processes of these three energy systems are given below. The amounts of GHGs emitted under these two scenarios for the production of one MWh of electricity were compared.

A. The baseline scenario

Fossil fuel

Coal produced in Australia was taken as the fuel source. The emissions in all steps of production including the extraction of surface coal, processing, transportation, storage and conversion in heat and power plants were considered in the comparison. The following Australian train diesel freight data obtained from the GEMIS database was used to estimate emissions in the transportation of coal. An Australian coal boiler with the following design specifications available in this database, was considered as the boiler used in burning coal.

Australian train diesel freight	**Australian coal boiler**
Specific consumption 25.2 MJ per km	Power 50MW
Mileage 150,000 km per year	Operating time 4500 hours per annum
Life time 25 years	Life time 25 years
Tonnage 100 tonnes	Efficiency 85 per cent

Bagasse

Bagasse is a by-product of the sugar industry and all the GHGs emitted in producing bagasse are associated with the production of sugar. Clearly, the cost of producing bagasse is included in the production of sugar. As far as the production process of sugar is concerned, cost of producing bagasse is marginal. Therefore, the GHGs emitted during the production of sugarcane, transport of cane to the mills and production of sugar were excluded from this analysis. Only the GHG emissions emitted during conversion of bagasse to heat energy in boilers were included in the analysis. A boiler with the following design specifications was included in the evaluation.

Power 10.00 MW
Operating time 1500 hours per annum
Lifetime 25 years
Land use 40 m^2
Efficiency 80 per cent

B. Camphor wood chips and residues of sugar industry as energy sources

The project plans to use woodchips of camphor laurel for bioenergy in the sugar mills. Trees are to be poisoned and to be kept for a few weeks until they reach the required moisture level of 25 per cent. The trees are felled for both timber and bioenergy. The SFNSW has estimated that about 10 per cent of total woody biomass can be used for sawn wood products and the rest for bioenergy. The remaining 90 per cent woody biomass will be converted to wood chips on site and these chips will be transported by means of trucks to the sugar mills for storage. These chips are then burnt in boilers to produce electricity generation. The GHGs emitted in all the steps, from on-site processing to ultimate use (burning in heat and power plants), were taken into account in the comparison.

The information in the GEMIS database was used for the evaluation of GHG emissions in each of the steps from harvesting through to ultimate burning in boilers. The design details of the machinery for harvesting, chipping, transportation and boilers are given in Table 3.2. A transportation distance of 50km is assumed for the study. The following data pertaining to 'truck-very-big-diesel-rural-generic' available in this database was used to estimate the emissions in the transportation process.

Truck-very-big-diesel-rural-generic

Specific consumption 15.78 MJ per km

Mileage 80,000 km per annum

Lifetime 30 years

Tonnage 13.9 tonnes

Table 3.2: **Design details of the machinery and boilers**

Design	Harvesting	Chipping	Boiler
Power	1.0 tonne/hour	1.00 MW	5.0 MW
Operating time	5000 hours/ annum	2500 hours/ annum	2500 hours/ annum
Life time	20 years	20 years	20 years
Land use	-	100 m^2	50 m^2
Efficiency	100%	99%	85%

As camphor biomass is expected to supplement bagasse to replace fossil fuel, the following combinations of camphor and bagasse were used to estimate the GHG emissions.

Table 3.3: **The different combinations of energy from camphor biomass and bagasse assumed under the baseline scenario**

Combination	Amount of energy from woodchips (%)	Amount of from bagasse (%)
1	10	90
2	20	80
3	30	70
4	40	60
5	50	50

3.1.5 Emissions from residues after clearing and extraction

The remaining parts of trees after the extraction of woody biomass in the field will be burnt to clear the land for replanting. These include residues of above ground biomass after extraction and the biomass remaining below ground. As stated in Chapter 2, these residual parts form a significant portion in total GHG emissions. The clearing and extraction followed by burning of the residues immediately releases GHGs while the remaining underground parts slowly emit GHGs with decay. Therefore, this component has to be taken into account because these emissions might be significant in comparing the emissions with and without the project. So far, no studies have been undertaken on such emissions related to this project. Also, the lack of information on these emissions in the available literature is a constraint to the integration of this component into the analysis. However, the following procedure was adopted to take into account these emissions.

Based on the general estimate of 40 per cent of these emissions from total emissions given by Graetz (1998, 245) for Australia, a sensitivity analysis was performed to estimate the total GHG emissions in the harvest-reforestation project. Different emission rates around this estimate, 5, 10, 20, 30, 40, 50 and 60 per cent were used in this sensitivity analysis. These emission rates were chosen on the basis of below ground biomass estimates given by Brown (1997) for tropical and subtropical forests outlined in Chapter 2. Emissions per tonne of wood were used to estimate the total emissions from camphor clearing. Carbon content in generic wood available in GEMIS database was used to estimate CO_2 emissions.

Formula 3.1 was used to calculate the emissions from this residual matter. It was assumed that the residual parts after clearing and extraction would completely decay and emit GHGs during the project period of 30 years.

$$E = c \times w \times B \qquad [3.1]$$

Where

E = Emissions from residues (tonnes)

w = % of residues from total above ground woody biomass

B = Total above ground biomass (tonnes), and

c = Emissions per tonne of wood chips

3.1.6 Evaluation of GHG benefits of the project

In the baseline scenario, camphor laurel sequesters CO_2 in the atmosphere. In the project, every hectare of camphor laurel infested land is replanted with eucalypt seedlings soon after harvesting. These seedlings sequester atmospheric CO_2 during growth. Considering the land area under the annual replanting programme, the higher sequestration capability of eucalypts compared with camphor laurel and the amount of CO_2 sequestered by 30,000 hectares of camphor laurel, it was assumed that the difference in carbon sequestration between these two scenarios is negligible in a 30-year project period.

Consequently, the differences in GHG emissions between the baseline scenario and the mitigation scenario were used to assess the carbon benefits of the project proposed by SFNSW. The two sugar mills together plan to produce 60MWh of electricity from bagasse and woodchips with the project. Therefore, 60MWh were taken as the amount of electric power produced with bagasse and coal under the baseline scenario for the calculation of the differences in GHG emissions between the two scenarios. The index GWP was used to assess the cumulative effect of the three gases because of differences in the relative radiative effects of various GHGs. However, the indirect effects of N_2O on the global warming process were not included in this analysis.

In addition to assessing the size of GHG emissions of these two alternatives, an evaluation of net social benefits is important in making a decision. A social cost-benefit analysis framework can be adopted to compare the various alternatives for the control of camphor laurel. In such an approach, the social opportunity cost of all the resources used for each alternative is compared with the social value of all the associated benefits. The difference between the social benefits and social costs gives an estimate of net social benefit. From an efficiency point of view, the project alternative with the highest net social benefit is most desirable. In certain situations, distributional consequences of the projects may be taken into account along with efficiency in the final choice of the project. In the following section, the items of costs and benefits for the various alternatives are identified and the approach to assessment outlined.

3.2 Economic feasibility of the project

This study focuses on the following two alternatives.

(a) Indefinite postponement of camphor control

This deferring action is the same as the baseline option, which allows the camphor laurel to continue its natural spread into the future.

(b) Implementation of a project to control camphor

Among the different benefit cost analysis criteria discussed in Chapter 2, NPV was adopted to assess the net benefits of these two alternatives. A sensitivity analysis of discount rate was performed to assess the effect of discount rate on NPV. Discount rates from 1 through 10 per cent were used to discount the stream of costs and benefits in this analysis. Formula 3.2 was used to calculate the NPV.

$$NPV = \sum_{t=0}^{T} \cdot \frac{(B_t - C_t)}{(1+i)^t} \qquad [3.2]$$

Where,

Bt = total benefits at year t

Ct = total cost at year t

t = time in years

i = Discount rate

The following assumptions were made in the calculation of NPV.

(a) The prices of inputs and outputs of the project remain unchanged during the project period;

(b) The three sugar mills continue to use the same technology for power generation during the project period; and

(c) Implementation of this project is not significant enough to affect any other part of the economy.

The social benefits and social costs of these two alternative actions and the techniques adopted to estimate these benefits and costs are discussed below.

3.2.1 Indefinite postponement of camphor control

There are benefits and costs associated with keeping camphor in the land. Although there are no direct benefits of keeping camphor in the land, camphor trees act as carbon storage while also sequestering carbon in the atmosphere. Therefore, these two service functions were considered as the benefits of keeping camphor. On the other hand, deferring control of this noxious weed increases the resources that would be required for future clearing. Also, the landowners suffer some loss of production and income due to their inability to graze stock at the current level under the dominant and codominant camphor canopy areas. In addition, there is a future burden on land managers due to the further spread of this weed, which will expand significantly throughout the area. These negative effects are costs to society. Nevertheless, it must be recognised that camphor laurel has an alternative use as a potential energy source for sugar mills and it could reduce GHG emissions if substituted for fossil fuel.

It was assumed that the two sugar mills in the area would continue to use bagasse and fossil fuel for the next 30 years in the absence of the project. The anticipated benefits and costs of this option are summarised in Table 3.4.

Table 3.4: **A summary of benefits and costs of deferring control of camphor**

Benefits	Costs
1. A carbon storage	1. Increasing cost of clearing in future
2. Sequestering carbon in the atmosphere	2. Loss of income for land owners
-	3. Losses due to further spread
-	4. Opportunity cost of the land
-	5. Foregone benefits of GHG emissions reduction

3.2.2 Values of the flows of costs and benefits

Carbon storage: The benefit of carbon storage was taken as a one-off value rather than an annualized value that was assumed to be sustainable. The value of carbon stored in camphor at the commencement of the project was estimated by using unit costs of carbon sequestration estimated by ABARE (1994, 9).

Sequestration of CO_2: The dollar value of CO_2 sequestering by camphor was calculated using unit costs of carbon sequestration estimated by ABARE (1994, 9). This benefit was taken as the value of net carbon storage occurring at the end of the project period.

Increasing cost of clearing in future: The respective land areas under dominant, co-dominant and scattered crown covers, and the relevant per hectare cost estimates were used to estimate annualized values of this cost.

Loss of income for the landowners: Annual foregone income was calculated by using per hectare estimates for dominant, co-dominant and scattered crown covers and the land areas under these crown covers.

Potential future income loss: This cost was assumed to be a negligible amount within the total cost.

Opportunity cost of land: In a well-functioning market, the price of a block of land reflects the present value of the stream of net benefits that can be derived into the future by the most appropriate use. In other words, the price of land represents its capitalised value. It was observed during the field visit that a block of land free of camphor fetches a higher price than a similar block infested with camphor laurel. This could be because the present value of the stream of benefits that can be expected from camphor infested land is lower than that of a camphor-free land. It can, therefore, be inferred that the opportunity cost of sustaining camphor in a block of land is the market price of a block of camphor free land. As noted during the field study, the market price of land infested with camphor is about $2500 per hectare while land free of camphor is worth about $5000 per hectare. This price of camphor free land was used to estimate the opportunity cost of land infested with camphor laurel at the commencement of the project.

Foregone benefit of GHG emissions reduction: The deferring option prevents the society from taking advantage of the opportunity to use camphor as an energy source, in lieu of fossil fuel, in nearby sugar mills. The major benefit of such a substitution of camphor laurel biomass for fossil fuel is the reduction in carbon emissions. Any potential benefit from such energy substitution is foregone as a result of sustaining camphor laurel. Therefore, this foregone benefit must be treated as a cost to society. Equivalently, this is the cost of current emission in the mills. Estimated unit cost of carbon sequestration (ABARE, 1994, 9) was used to estimate this foregone benefit. This was calculated as a cumulative cost at the end of the project life.

3.2.3 Estimation of benefits and costs of deferring control of camphor laurel

The value to society of goods and services traded in competitive markets can be inferred from the market prices. However, the service functions of storing carbon in this vegetation and the sequestering service of CO_2 in the atmosphere are not traded in the market. Therefore, unit values estimated by ABARE (1994, 9) for carbon sequestration were used as there are no direct market prices to value these non-market services. The SFNSW (2000, 11) has estimated unit costs for the increasing cost of clearing in future and the loss of income for the landowners. These cost estimates were used for the benefit cost assessment of this option. However, the SFNSW has not estimated the costs to society as a result of further spread of camphor in the future. For this study, this cost was not estimated because of time and resource constraints. Estimated unit cost of carbon sequestration (ABARE 1994, 9) was used to value the foregone benefits of GHG emissions reduction. A summary of the approaches adopted for the estimation of the items of benefits and costs is provided in Table 3.5.

Table 3.5: **Estimation of the benefits and costs of deferring action**

Benefits/ Costs	Valuation Method
Carbon storage	Estimated costs of carbon sequestration by ABARE
Sequestration of CO_2	As above
Increasing cost of clearing in future	Estimates of SFNSW
Loss of income for the land owners	Estimates of SFNSW
Cost of land	Opportunity cost (market value of camphor free land)
Cost of GHG emissions in the mills	Estimated costs of carbon sequestration by ABARE

Note: ABARE (1994, 9) and SFNSW (2000, 11) are the sources of figures here

3.2.4 The project to control camphor

This project gives economic and environmental benefits while incurring certain costs. The costs of the factors of production in the harvesting-afforestation, and the benefits of the project must be taken into account for the evaluation of this alternative. Costs of machinery and equipment used for harvesting, on-site processing, land conversion, plantation establishment and maintenance, the modification costs to existing boilers to generate power were taken as the capital costs. Costs of labour and materials of harvesting, on-site processing, transport, land conversion, plantation establishment and maintenance, and power generation were included for each of these operations. Management costs were included in overhead costs of the project, overhead costs of establishment and maintenance costs of eucalypt plantations. Salaries paid to the staff and travel costs were taken as overhead costs. Costs of GHG emissions and impacts on biodiversity were taken as the external costs of the project. However, biodiversity effects were not be incorporated in the study.

The outputs of the project, such as camphor and eucalypt biomass and timber, were taken as benefits of the project. As discussed in Chapter 1, carbon sequestered by eucalypts, the reduction in carbon emission as a result of decrease in fossil fuel use by the two sugar mills and increase in employment opportunities are expected with the project. These positive effects were considered as benefits of the project. The costs of the factors of production and the benefits of the project are shown in Table 3.6.

Table 3.6: **Costs and benefits of the project**

Costs	Benefits
Land cost	Camphor bioenergy
Harvesting cost	Camphor timber
On-site processing cost	Carbon sequestered by eucalypts
Transport cost of chips	Eucalypt bioenergy
Land conversion costs	Eucalypt timber
Plantation establishment costs	Carbon saved in fossil fuel
Plantation maintenance costs	Employment benefits
Overhead cost of plantations	-
Capital costs	-
Cost of power generation	-
Overhead cost of the project	-
Loss of biodiversity	-
External costs of GHG emissions	-

3.2.5 The flows of costs and benefits

Costs and benefits were estimated by multiplying physical quantities of inputs and outputs by their unit prices. The approaches adopted to estimate the costs and benefits of the project are outlined below.

Opportunity cost of land: The market price of a block of land infested with camphor laurel reflects the present value of the flow of net benefits that can be derived into the future. Therefore, in this case, the opportunity cost of land was taken as the market price of a block of camphor infested land. As discussed in Chapter 1, the harvest-reforestation programme would be continued at the rate of 600 hectares per year during the first 10 years of the implementation of the project, declining to 300 hectares per year after 10 years, and subsequently to 200 hectares per annum, after 20 years (SFNSW, 2000, 2). Land area under the project in each year was used to estimate the opportunity cost of land in each year.

Harvesting cost: Harvesting costs include both the costs of poisoning trees and logging cost. These two costs per tonne were added together to obtain total harvesting cost per tonne. Average harvesting cost per hectare was estimated by multiplying this unit cost estimate of SFNSW (1999a, 2) with the average above ground biomass per hectare. Then annual harvesting costs were calculated by using per hectare harvesting costs and the land area under the project in each year.

On-site processing cost: Formula 3.3 was used to estimate the annual on-site processing (chipping) costs. As per the estimates of SFNSW (1999a, 2), it was assumed that only 90 per cent of above ground woody biomass would be available for chipping.

$$AP_i = 0.9 \times B \times PC \times L \ldots\ldots\ldots\ldots\ldots\ldots\ldots [3.3]_i$$

Where,

AP_i = Processing cost in year i

c= Processing cost per tonne

B = Total above ground woody biomass per hectare

L_i = Land area under the project in year i

Land conversion costs: The land area under the project in each year was used to calculate annual land preparation costs during the project.

Transport costs: Formula 3.4 was used to calculate the annual transport costs of camphor wood chips to the two sugar mills. It was assumed that 90 per cent of woody above ground biomass converted to wood chips. An average carting distance of 60km was taken to estimate these costs.

$$TC = 0.9 \times T \times D \times B \times L \ldots\ldots\ldots\ldots\ldots\ldots\ldots [3.4]$$

Where,

t = Transport cost per tonne per km

D = Transport distance (km)

B = woody above-ground biomass (tonnes per hectare)

L = Extent of land harvested (hectare)

Plantation establishment costs: The land area of plantation establishment under the project in each year was taken to estimate annual costs of plantation establishment.

Plantation maintenance costs: According to the estimates of SFNSW (Lamb, K., SFNSW, pers. comm. 05/03/2001), fertiliser is applied in the second year while first thinning and final harvesting are done in year 10 and 20 respectively after planting. Annual plantation maintenance costs were calculated based on the estimated costs of these silvicultural practices by SFNSW and the plantation establishment time frame and extent of the project.

Overhead costs of plantations: Annual overhead costs of plantations were calculated using the area of land planted each year during the project.

Overhead costs of the project: Annual overhead costs were estimated based on the opinion of the project staff, present staff strength of the project, and anticipated salaries and travel costs of the staff.

Capital costs: It was assumed that the capital investment is made in the first year of the implementation of the project and there is no salvage value of this investment at the end of a 30 year period.

Operational costs of power generation: Estimates of SFNSW (1999b, 30) were used to obtain the annualized values of these costs.

External costs of GHG emissions: Cost of cumulative GHG emissions with the project at the end of the project life was calculated using unit carbon sequestration costs and the cumulative GHG emissions estimated under the mitigation scenario.

Bioenergy from camphor and eucalyptus: Estimates of SFNSW (1999a, 2) was used to estimate the value of this benefit. Formula 3.5 was used to estimate the annual monetary values of these benefits.

$$Bb_i = Q_i \times p \qquad [3.5]$$

Where,

Bb_i = Value of camphor and eucalyptus bioenergy in year i ($ per annum)
Qi = Quantity of woodchips to be supplied in year i (tonnes per annum)
p = Estimated delivered price of woodchips ($ per tonne)

Camphor and eucalyptus timber: The monetary value of annual timber benefits from these two species was estimated by using annual timber yields of the two species and the prevailing market prices.

Carbon sequestered by eucalypts: The dollar value of amount of carbon sequestered by eucalypts at the end of the project was estimated using the unit costs of carbon sequestration estimated by ABARE (1994, 9).

Carbon saved in fossil fuel: The difference in GHG emissions between the baseline scenario and the mitigation scenario gives the amount of GHGs emitted from coal burning in CO_2 equivalents. Therefore, this difference was used to estimate the carbon saving benefit. This benefit was taken as a one-off benefit occurring at the end of the project period. The unit costs of carbon sequestration by ABARE (1994, 9) were used to estimate the dollar value.

3.2.6 Estimation of the costs and benefits of the project

Costs and benefits were valued as dollars per unit of physical quantities. All the costs except operational costs of power generation were valued. As discussed earlier, opportunity cost of land was used to value the cost of land. As already discussed, opportunity cost was taken as the market price of camphor-infested land in the region. Estimates of SFNSW were used to value the unit costs of land conversion, plantation establishment and plantation maintenance, and annual overhead costs of raising and maintaining plantations until harvesting. Information collected during the field visit and opinions of the experienced project staff were used to value the on-site processing cost, transport cost of chips, harvesting cost and overhead costs of the project. Estimated unit cost of carbon sequestration by ABARE (1994, 9) was used to value the external costs of GHG emissions.

Because of commercial confidentiality, a default value of estimated present value of the capital cost of machinery and equipment, and the cost of upgrading the boiler capacities by SFNSW (1999b, 27) were used in the benefit cost analysis. This cost was taken as 35 million dollars. Estimates of SFNSW (1999b, 30) were used to estimate operational costs of power generation. As discussed in Chapter 2, there could be both positive and negative effects on biodiversity due to the replacement of camphor. However, inclusion of these effects on biodiversity in the analysis is beyond the scope of this study.

As far as the valuation of benefits is concerned, the estimated delivered prices of camphor and eucalypt woodchips by the SFNSW (1999a, 2) were used to value camphor and eucalypt bioenergy. Market prices were used to value the timber benefits (camphor and eucalypts) of the project. Estimated costs of carbon sequestration by ABARE (1994, 9) were used to value the carbon saved in fossil fuel and carbon sequestered by eucalypts. The employment benefits of the project (discussed in Chapter 1) were valued based on the estimated salaries and wages to be paid to the workers. The valued annualized employment benefits were deducted from the annualized costs in calculating NPV. It was assumed that unemployed people would be recruited to fill vacancies in calculating the employment benefits of the project. The approaches adopted for the estimation of benefits and costs of the project are summarised in Table 3.7. All the data used in this study are presented in Appendix VI.

In summary, this Chapter has provided methods, which can be used to achieve the objectives of this study. LCA was used to estimate the GHG emissions in the baseline scenario and the mitigation scenario. The GHG emissions of the residues after clearing and extraction were added to the GHG emissions from energy generation in the mitigation scenario to obtain overall GHG emissions in this scenario. These estimates were useful in assessing which alternative action emits less GHGs. Also, BCA was used to assess economics of the two alternative actions. The results are discussed in Chapter 4.

Table 3.7: **Approaches used to value costs and benefits of the project**

Cost/ benefit	Valuation approach
Land cost	Opportunity cost (the market value of camphor free land)
Harvesting cost	Estimates of SFNSW (1999a, 2)
On-site processing cost	as above
Transport cost of chips	as above
Land conversion costs	Estimates of SFNSW (Lamb, K., SFNSW, pers. comm. 05/03/2001)
Plantation establishment costs	as above
Plantation maintenance costs	as above
Overhead cost of plantations	as above
Operational costs of power generation	Estimates of SFNSW (1999b, 30)
Capital costs	Estimates of SFNSW (1999b, 27)
External costs of GHG emissions	Estimated costs of carbon sequestration by ABARE (1994, 9)
Overhead cost of the project	Information collected during the field visit and expert opinion
Camphor bioenergy	Estimates of SFNSW (1999a, 2)
Camphor timber	Market price
Carbon sequestered by eucalypts	Estimated costs of carbon sequestration by ABARE (1994, 9)
Eucalypt bioenergy	Estimates of SFNSW (1999a, 2)
Eucalypt timber	Market price
Carbon saved in fossil fuel	Estimated costs of carbon sequestration by ABARE (1994, 9)
Employment benefits	Salaries and wages

4. Chapter 4. Results and Discussion

The results of the GHG modelling and the benefit cost analysis are discussed in this Chapter. The harvest-reforestation project is feasible only if it reduces GHG emissions and yields additional net benefits to society over the deferring action. This Chapter is divided into two main sections in order to address these two issues separately. Section 4.1 discusses the GHG emissions from the energy generation processes in the two scenarios, GHG emissions from residues after clearing and extraction, and the evaluation of GHG mitigation benefits of the project. Section 4.2 discusses the economics of the alternative actions.

4.1 Greenhouse gas emissions from the energy generation processes

Energy generation processes in the baseline scenario were burning of bagasse and coal while burning of bagasse and woodchips were the energy generating processes under the project. The estimation of GHGs at complete lifecycle level has taken into account the emissions from the production of all the raw materials up to the end use of the products. Lists of these GHG emitting processes are shown in Appendices 1 to 5. Emissions from burning bagasse, coal and woodchips, nitrogen fertiliser to be applied for eucalypt plantations, mechanical plantation establishment, mechanical logging, chipping, transport of wood chips and residues after clearing and extraction have been taken as the GHG emitting processes at the reference area level.

4.1.1 Greenhouse gas emissions at the complete lifecycle level

GHG emissions of the baseline scenario at the complete lifecycle level are shown in Table 4.1. These emission levels were estimated considering the complete lifecycles of generating energy from coal and bagasse. The complete lifecycles of these processes exceed the geographic boundary of the reference area because the production of some of the inputs such as petroleum products required for these processes takes place outside this region and in some cases, outside the country. Generating energy from coal and bagasse emits CO_2, CH_4 and N_2O. GHG emissions in CO_2 equivalents increase as more and more energy is derived from coal. This is mainly due to the high CO_2 emissions from coal burning. However, CH_4 and N_2O emissions decrease with the increase in coal use. This is mainly because a reduction of bagasse use reduces the emissions of these two gases CO_2 accounts for more than 99 per cent of the total GHG emissions.

Table 4.1: **Greenhouse gas emissions of the baseline scenario at the complete lifecycle level**

Combinations of energy from bagasse and coal	Greenhouse gas emissions (tonnes)			
	CO_2 equivalents	CO_2	CH_4	N_2O
1 (10% energy from coal and 90% energy from bagasse)	0.35	0.32 (99.75%)	7.5E-04 (0.23%)	3.7E-05 (0.012%)
2 (20% energy from coal and 80% energy from bagasse)	0.39	0.37 (99.8%)	6.8E-04 (0.18%)	2.3E-05 (0.006%)
3 (30% energy from coal and 70% from bagasse)	0.41	0.39 (99.8%)	6.5E-04 (0.166%)	1.8E-05 (0.004%)
4 (40% energy from coal and 60% from bagasse)	0.41	0.40 (99.8%)	6.4E-04 (0.159%)	1.5E-05 (0.003%)
5 (50% energy from coal and 50% from bagasse)	0.42	0.40 (99.8%)	6.3E-04 (0.157)	1.3E-05 (0.003%)

Note: Emissions from the production of 1MWh of electricity

GHG emissions of the project scenario are summarised in Table 4.2. There is a small increase in GHG emissions (in CO_2 equivalents) as more and more energy comes from wood. This increase is mainly due to the increase in CO_2 emissions while the emissions of other two GHGs remain more or less the same with the increase in energy from wood. The contributions to CO_2 equivalents from CH_4 and N_2O are much higher than that of CO_2, as GWP of CH_4 is about 21 times greater than that of CO_2. It is about 310 times greater in the case of N_2O than that of CO_2. Because of the small increase in the total emissions associated with increasing energy from wood, wood can be considered as a good supplementary energy source for bagasse. However, the substitution of wood for coal as a supplementary energy source for bagasse depends on the differences in GHG emissions between the baseline scenario and the project scenario.

Table 4.2: **Greenhouse gas emissions of the project option at the complete lifecycle level**

Energy from wood and bagasse	Greenhouse gas emissions (tonnes)			
	CO_2 equivalents	CO_2	CH_4	N_2O
1 (10% energy from wood and 90% energy from bagasse)	0.064	1.24E-03	1.18E-03	1.25E-04
2 (20% energy from wood and 80% energy from bagasse)	0.065	2.66E-03	1.14E-03	1.20E-04
3 (30% energy from wood and 70% from bagasse)	0.065	4.33E-03	1.09E-03	1.22E-04
4 (40% energy from wood and 60% from bagasse)	0.066	6.31E-03	1.03E-03	1.24E-04
5 (50% energy from wood and 50% from bagasse)	0.067	8.68E-03	9.60E-04	1.18E-04

Note: Emissions from the production of 1MWh of electricity

There are significant differences in GHG emissions between the baseline scenario and project scenario at the complete lifecycle level. Differences of GHG emission levels between the baseline scenario and the project scenario are summarised in Table 4.3. The differences increase when more wood is substituted for coal. The real difference between the emissions under these two scenarios depends on actual combination of energy sources used by the sugar mills in generating their own energy. However, these results represent not only the Australian contribution but also some other countries because some parts of the lifecycle having taken place beyond the reference area and the country. As this study focuses on GHG emissions at the project level, it is important to consider the GHG emissions from the energy generation processes in the reference area.

Table 4.3: **Differences of greenhouse gas emission levels between the baseline scenario and project scenario at the complete lifecycle level**

Energy combinations in baseline scenario and mitigation scenario	Greenhouse gas emissions (tonnes)		
	Baseline scenario	Project scenario	Differences in GHG emissions
1	0.345	0.064	0.282
2	0.388	0.065	0.323
3	0.405	0.065	0.340
4	0.414	0.066	0.348
5	0.420	0.067	0.353

Note: 1. Emissions from the production of 1MWh of electricity

2. Energy combinations one through five represent the combinations of energy coming from bagasse and coal in the baseline scenario and bagasse and woodchips in the mitigation scenario

4.1.2 Greenhouse gas emissions within the reference area

The reference area for this study was taken as Tweed and Byron Shires, NSW. GHG emissions of the baseline scenario within the reference area are summarised in Table 4.4. In the baseline scenario, burning of coal and bagasse are the two processes taken as being at the reference area level. These two processes account for about 95 per cent of the GHG emissions at the complete lifecycle level because they are the major energy generating processes of the baseline emitting most of the GHGs. The emissions from these two processes also show the same trends as the total GHG emissions at complete lifecycle level. Coal accounts for about 95 per cent of the total GHG emissions at 10 per cent energy generation level from coal. There is a significant increase in GHG emissions as more and more energy comes from coal. The results indicate that there is a potential for mitigating a considerable amount of GHGs by supplementing bagasse with another bioenergy source rather than coal.

A summary of GHG emissions of the processes of the project scenario within the reference area is shown in Table 4.5. These emissions account for 87 per cent and 98 per cent of the complete lifecycle emissions when generating 10 per cent and 50 per cent of total energy requirement respectively from coal. The major GHG emitting processes is bagasse among all the processes at the reference area level. When compared with the emissions from bagasse burning, GHG emissions from burning wood chips are a minute component as the emissions from wood chips range from 0.7 per cent to 4.7 per cent of the total emissions in generating 10 to 50 per cent of the total energy requirement. This huge difference is due to the higher N content in bagasse than that of woodchips. Bagasse contains 0.38 per cent of N on a dry basis while the N content in wood is only 0.07 per cent (*Oeko-Institut* 2000a). Therefore, burning of bagasse emits more N_2O that translates to huge amounts in CO_2 equivalents. The emissions from nitrogen fertiliser to be applied to eucalypt plantations result in more GHGs in CO_2 equivalents than those of burning woodchips due to the same reason. However, these results are attributed to the emissions data for generic wood available in the GEMIS database. Therefore, the actual emissions from camphor are needed for a real comparison of the mitigation scenario with the baseline scenario.

Table 4.4: **Greenhouse gas emissions of the baseline scenario within the reference area**

Process	Greenhouse gas emissions (tonnes)				
	Benchmark 1	Benchmark 2	Benchmark 3	Benchmark 4	Benchmark 5
Burning of coal	0.316 (95.5%)	0.363 (97.8%)	0.383 (98.7%)	0.393 (99.2%)	0.399 (99.5%)
Burning of bagasse	0.015 (4.5%)	0.008 (2.2%)	0.005 (1.3%)	0.003 (0.8%)	0.002 (0.5%)
Total	0.331(100%)	0.371(100%)	0.388(100%)	0.396(100%)	0.401 (100%)

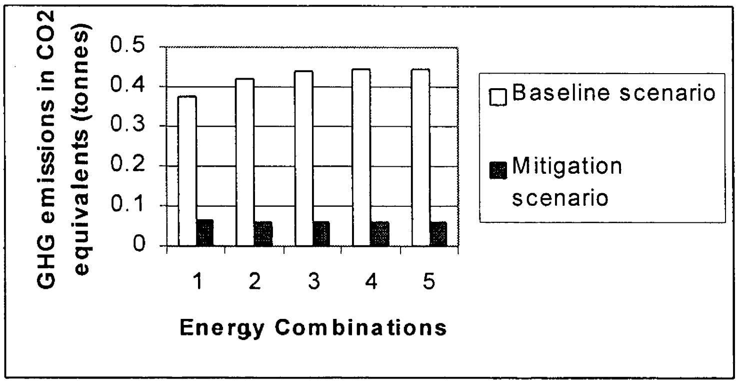
Note: 1. Emissions from the production of 1MWh of electricity
2. Benchmarks 1 through 5 represent the combinations of energy from bagasse and coal

Table 4.5: **Greenhouse gas emissions of the project scenario at the reference area level**

Process	Greenhouse gas emissions (tonnes)				
	1	2	3	4	5
Burning of bagasse	0.061 (97.4%)	0.059 (94.3%)	0.056 (90.6%)	0.052 (85%)	0.048 (82%)
Nitrogen fertiliser for eucalyptus plantation	0.0007 (1.17%)	0.0016 (2.6%)	0.0026 (4.2%)	0.0042 (6.8%)	0.0047 (8%)
Burning of woodchips	0.0005 (0.73%)	0.0010 (1.5%)	0.0016 (2.6%)	0.0026 (4.2%)	0.0029 (5%)
Mechanical plantation establishment	0.0004 (0.7%)	0.0009 (1.5%)	0.0015 (2.5%)	0.0025 (4%)	0.0028 (4.8%)
Mechanical logging	3.02E-09 (≅0%)	6.49E-09 (≅0%)	1.06E-08 (≅0%)	1.70E-08 (≅0%)	1.96E-08 (≅0%)
Chipping	3.34E-10 (≅0%)	7.35E-10 (≅0%)	1.19E-09 (≅0%)	1.92E-09 (≅0%)	2.17E-09 (≅0%)
Transport of wood chips	2.50E-11 (≅0%)	5.40E-11 (≅0%)	8.79E-11 (≅0%)	1.41E-10 (≅0%)	1.60E-10 (≅0%)
Total	0.0628 (100%)	0.0622 (100%)	0.0614 (100%)	0.0613 (100%)	0.0583 (100%)

Note: 1. Emissions from the production of 1MWh of electricity
2. Energy combinations 1 through 5 represent the energy combinations of bagasse and woodchips in the mitigation scenario

Figure 4.1: **Graphical representation of the greenhouse gas emissions of the baseline scenario and the project scenario**



Note: Energy combinations 1 through 5 represent the energy combinations of bagasse and woodchips in the mitigation scenario

A summary of the GHG emissions of the baseline scenario and the project scenario and their differences is shown in Table 4.6. The emission levels of these two scenarios in CO_2 equivalents are depicted in Figure 4.1. As at complete lifecycle level, there is a significant difference in GHG emissions between the baseline scenario and the project scenario in the reference area. This suggests that there is potential to mitigate GHG emissions by supplementing woodchips with bagasse. Also, it seems that the proposed project leads to considerable reduction of GHG emissions. However, GHG emissions from the residues after clearing and extraction must also be taken into account for a comparison of these two scenarios.

Table 4.6: **Greenhouse gas emissions difference between the baseline scenario and the mitigation scenario**

Energy combinations in the two scenarios	Greenhouse gas emissions (tonnes)		
	Baseline scenario	Mitigation scenario	Difference between the two scenarios
1	0.377	0.063	0.314
2	0.422	0.062	0.359
3	0.438	0.061	0.377
4	0.445	0.061	0.383
5	0.447	0.058	0.389

Note: 1. Emissions from the production of 1MWh of electricity
2. Energy combinations 1 through 5 represent the energy combinations of bagasse and woodchips in the mitigation scenario

4.1.3 Greenhouse gas emissions from residues after clearing and extraction

In addition to the emissions from generating energy by burning bagasse and woodchips in the mitigation scenario, residues of trees remaining after clearing and extraction decay and emit CO_2 to the atmosphere. Estimated GHG emissions from these residues are shown in Table 4.7. There are considerable amounts of emissions associated with these residues. Also, there is a significant increase in the emissions as the percentage of residues increases. Consequently, there could be a significant increase in the emissions from the project if these emissions are added to the emissions from the energy generation processes. Therefore, it is important to include these emissions in the project scenario and to compare them with those of the baseline scenario in evaluating the GHG benefits of the proposed project.

Table 4.7: **Greenhouse gas emissions from residues after clearing and extraction**

Per cent of residues after harvesting and extraction	CO_2 emissions (000' tonnes)
5	257
10	514
20	1028
30	1542
40	2056
50	2569
60	3083

Note: Residues are expressed as a percentage of the above ground biomass

4.1.4 Evaluation of greenhouse mitigation benefits of the project

Burning camphor and eucalypt woodchips in the sugar mills and residues after clearing and extraction would add to GHG emissions, whereas the savings of GHGs in coal would reduce the emissions. GHG mitigation benefits of the project depend on how much carbon is saved in coal as the difference in carbon sequestration benefits of the two scenarios is negligible. A summary of the total GHG emissions of the two scenarios and their differences at the reference area level is given in Table 4.8. Results indicate that there are significant net GHG benefits of this project both at 5 per cent and 60per cent level of residues (as a fraction of total above ground biomass) that will completely decay and emit CO_2.

This suggests that the SFNSW's claim of GHG mitigation benefits of the project is still valid even when the overall effect of all the GHGs and emissions from woody debris are considered. As discussed in Chapter 1, the estimated foregone emission offsets from the deferring action by SFNSW is 7.2 million tonnes in CO_2 equivalents for an 80-year period. According to the results of this study, the GHGs saved in fossil fuel range from 3.8 to 6.8 million tonnes in CO_2 equivalents for 30-year project period. Inclusion of overall effect of all the GHG emissions including emissions from woody debris in this study and the difference in time period could be the reasons for this difference. GHG mitigation benefits of the project would be more if carbon accumulation in camphor and eucalypt timber were considered.

However, one must exercise caution in drawing any strong recommendation issue from these results due to the lack of information on amount of carbon stored in the residues of camphor laurel and the actual GHG emissions from this component. It must also be noted that data on the GHG emissions of the energy generation processes do not represent the real situation as most of these data belong to the energy generation processes of other countries. Although the biases associated with these data can be considered as cancelled out in the comparison of the two scenarios, their accuracy cannot be guaranteed. Therefore, further studies especially on these crucial emissions are important at this stage because of the Federal Government's focus on utilising environmental weeds such as camphor laurel as bioenergy sources in meeting the national renewable energy targets. In addition to the results of GHG emissions, results of the economic analysis should also be considered in making policy decisions.

Table 4.8: **Summary of the total Greenhouse gas emissions of the two scenarios and their differences at the reference area level**

Energy combinations in the two scenarios	Greenhouse gas emissions (000' tonnes in CO_2 equivalents)					
	Baseline scenario	Project scenario: Energy generation	Project scenario: Total emissions from both energy generation and residues		Difference between mitigation scenario and baseline scenario	
			Lower limit	Upper limit	Lower limit	Upper limit
1	5,944	993	1,250	4,077	-4,694	-1867
2	6,654	977	1,234	4,061	-5,419	-2592
3	6,906	961	1,218	4,045	-5,687	-2860
4	7,016	961	1,218	4,045	-5,797	-2971
5	7,048	914	1,171	3,998	-5,876	-3050

Note: 1. The lower limit and the upper limit represent the emissions from 5 per cent and 60 per cent of residual matter from total above ground biomass respectively

2. GHG emissions from the energy generation processes in the baseline and project scenarios are estimated for the production of 60MWh electricity for 30-year project period.
3. Energy combinations 1 through 5 represent the energy combinations of bagasse and woodchips in the mitigation scenario

4.2 Evaluation of the economic benefits of the alternative actions

4.2.1. Evaluation of the economic benefits of the deferring action

A summary of the estimated NPVs of the deferring action at different levels of the forgone benefits of GHG mitigation is given in Table 4.9. The results of the benefit cost analysis of this alternative action show that all the NPVs estimated for CO_2 emissions at 5 through 60 per cent of the residues levels (as a fraction of total above ground biomass) are negative. This is due to the high opportunity cost of mitigating GHGs from the camphor biomass and the opportunity costs of camphor infested lands that cannot be offset by the benefits of retaining this noxious weed. The results suggest that retaining camphor laurel intact give negative net social benefits to the society because of the GHG emissions in the sugar mills using and the opportunity cost of the camphor infested lands. Therefore, it can be recommended that alternative uses for these camphor laurel infested lands and biomass of this noxious weed are necessary to derive positive net economic benefits to the society.

Table 4.9: **Estimated net present values of the deferring action at different levels of the forgone benefits of Greenhouse gas mitigation**

Energy combinations of the baseline scenario	Net present value (million $)	
	5% residues level	60% residues level
1	-117	-90
2	-131	-104
3	-136	-108
4	-138	-110
5	-139	-111

Note: 1. Energy combinations 1 through 5 represent the energy combinations of bagasse and coal in the baseline scenario
2. Net present values are given at two residue levels as foregone benefits from camphor biomass have been calculated for 5 per cent and 60 per cent residue levels after clearing and extraction at 1 per cent discount rate
3. Per cent of residues are expressed as a percentage of total above ground biomass

4.2.2 Evaluation of the economic benefits of the proposed project

The results of the benefit cost analysis of this proposed project are shown in Table 4.10. The results indicate that the project yields positive net economic benefits only at 100 per cent CO_2 emissions from the 5 per cent residues of the total above ground biomass. The project is not feasible beyond these emissions levels as all other NPVs estimated beyond this residue level are negative. The main reason for this shift from positive net benefits to negative net benefits is the higher costs of GHG emissions from the residual matter. NPV increases as more and more wood biomass supplements bagasse. Therefore, a shift from the negative to positive economic benefits can be expected if these residues are incorporated into the energy generation process rather than allowing them to decay in the soil.

Table 4.10: **Estimated net present values of the project at different energy combinations and different levels of emissions from the residues after clearing and extraction**

Energy combinations in the mitigation scenario	Net present value (millions $)			
	Discount rate = 1%		Discount rate = 2%	
	5% residues level	10% residues level	5% residues level	10% residues level
1	1.33	-31.6	-23.1	-32.
2	15.4	-21.0	-12.6	-21.
3	20.8	-16.9	-8.4	-17.
4	22.9	-15.3	-6.88	-15
5	25.6	-13.1	-4.62	-13

Note: 1. Energy combinations 1 through 5 represent the energy combinations of bagasse and woodchips in the mitigation scenario
2. Per cent of residues are expressed as a percentage of total above ground biomass

Among the residues, the below ground biomass is a major component. Since the project is feasible at the 100 per cent emission level of CO_2 from a 5 per cent residue level, the above ground residues could be burnt. However, the remaining below ground biomass has to be extracted and used in energy generation to obtain positive net economic benefits. However, any specific recommendation cannot be drawn until real data is used to validate the results. Investigations of residue levels and emission levels with respect to camphor laurel may be valuable because of the Federal Government's focus on utilising environmental weeds such as camphor laurel as bioenergy sources for the sugar industry in meeting the national renewable energy targets. The results of the present study has limitations because of the exclusion of uncertainties on future rates of emissions, lack of valuation of joint benefits and joint costs in the analysis.

Despite these limitations, the results of the present study suggest that a harvest-reforestation strategy, where camphor laurel is harvested for energy generation primarily and the land replanted with fast growing eucalypt species, could yield net benefits to society. This is particularly so, under lower discount rates of the order of 1. Chapter 5 concludes this thesis, and summarises the argument and the evidence.

Chapter 5. Summary and Conclusions

5.1 Introduction

The control of camphor laurel in New South Wales (NSW) is important for landowners as its rapid spread would lead to increasing losses of income in grazing land. However, a major concern in controlling this noxious weed is the implications to carbon balance as it is a significant carbon sink. The State Forests New South Wales (SFNSW) has proposed a harvest reforestation project aimed at replacing camphor laurel with eucalypts and use of the biomass to supplement bagasse as an energy source in two sugar mills in Tweed and Byron Shires. The use of the biomass would replace coal, which is used at present. This study is concerned with such an approach to reduce carbon emissions, and has a specific focus on the proposed project. It investigates the level of net carbon emissions and the economics of achieving it.

Preliminary studies of SFNSW have shown that this project could lead to a favourable greenhouse gas (GHG) balance along with the control of camphor. However, SFNSW has not taken into account the overall effect of all the GHGs and the economics of the project. The objectives of the present study are to estimate all the relevant GHG emissions in all the steps of this project and to evaluate the economic benefits of the proposed project compared to doing nothing to control this weed. A Life Cycle Analysis (LCA) was used to estimate GHG emissions and a social benefit cost analysis was undertaken.

5.2 Summary of results

A key aspect of this study is the estimation of net GHG emissions using a LCA approach, where emissions of GHGs at all the steps are considered. The empirical approach entailed the use of GEMIS (Global Emission Model for Integrated Systems)-a software developed in Germany for such purposes. The software also provides a database, which was used in this study in addition to data obtained from previous studies at the SFNSW and the Australian Bureau of Agricultural and Resource Economics (ABARE).

The results of this study have shown that GHG emissions will fall significantly if woodchips from camphor laurel and subsequent eucalypt plantations substituted for fossil fuel in generating energy in the two sugar mills supplementing for bagasse. A considerable amount of residues are left, especially below ground after clearing trees. Although there are emissions associated with the residues, still there are significant net GHG benefits of this project both at low (5%) and high (60%) level of residues as a fraction of total above ground biomass. This study confirms the SFNSW's claim of GHG mitigation benefits of the project where the overall effect of all the GHGs is considered.

Another important feature of this study is that it includes explicitly the value of carbon sequestration services in the social benefit cost analysis. The results indicate that the project yields positive net economic benefits both at a low discount rate and high level of residues. The project is not attractive at a high residue level as the NPVs estimated beyond 5% residue level are negative, irrespective of the discount rate. In contrast, economic analysis of keeping camphor laurel has shown that the NPVs (net present value) are negative even at low discount rates. This is due to the high opportunity cost of mitigating GHGs through camphor vegetation in grazing land, amidst high emissions from sugar mills that use coal supplemented by bagasse.

5.3 Conclusions

Two main conclusions can be drawn from this study. First, allowing camphor laurel to exist and spread in grazing lands in the NSW as a means of sequestering carbon is costly to society, especially when there are opportunities to use that biomass as an alternative to fossil fuel in energy generation. Second, a harvest-reforestation approach to control camphor laurel would reduce the GHG emissions when a part of the biomass is used as energy source to replace coal. It is desirable from society's standpoint when a low level of below ground biomass is left to decay. The society could derive positive net benefits from such a project under a lower discount rate, which is justifiable for long term environmental projects such as mitigation of global warming or climate change.

However, caution must be exercised in drawing strong conclusions or prescriptions without further refinement of technical data. Actual GHG emission rates for camphor laurel and proportion of below ground biomass were not available. Only generic data for hardwood species was used in this study. Another limitation of the empirical study is that some of the technical data used from the GEMIS database relates to other countries and hence not specific to the area under study.

This study implicitly assumed that there are no distortions in capital and labour markets and hence did not undertake shadow pricing of these factors of production in the social benefit cost analysis. Future studies could examine the validity of this assumption. This study did not model the growth of eucalypts that replaces camphor and its carbon sequestration over time. A further study should include detailed information of carbon sequestration. Apart from generation of country specific technical data, a further study may be required to investigate the economics of such project when below ground residues of camphor laurel can be burnt for energy generation. It is likely that additional energy generation from such residues would yield higher net benefits to society.

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Appendix 1. Comparison of greenhouse gas emissions from option 1 and option 6[2]

Process	Greenhouse gas emissions (tonnes in CO_2 equivalents) Option 1	Option 6	Location
Sum	101.706E3	4.59868E3	
coal-boiler-AUS'NSW	92.8584E3	0.0000000	Australia
bagasse-ST-FJ-FSC'NSW	4.39937E3	4.39937E3	Fiji
Xtra-surface\coal-AUS	2.84113E3	259.66E-6	Australia
coal-ST-AUS	649.37404	6.8289E-3	Australia
train-diesel-freight-AUS	361.61790	1.4035E-3	Australia
diesel motor-AUS	241.26576	138.78E-6	Australia
chem-inorg\nitric acid	96.163873	20.357884	Germany
gas-GT-AUS	55.353762	582.61E-6	Australia
oil-heavy-boiler-AUS	44.211147	124.08E-6	Australia
chem-inorg\ammonia	38.723294	8.2140034	Germany
waste-ST-AUS	22.892463	240.74E-6	Australia
gas-boiler-D	18.627489	4.2437401	Germany
blasting (ANFO)	9.1988179	116.46E-6	generic
oil-heavy-ST-AUS	9.1758514	96.494E-6	Australia
metal\pig-iron-D	6.9197999	1.1088333	Germany
xtra-onshore-primary\oil-crude-OPEC	6.2510714	702.65E-3	OPEC
ship (ocean)	5.1335555	579.39E-3	generic
Xtra-offshore-secondary\oil-CAN	3.7469238	58.307E-6	Canada
Xtra-offshore-primary\oil-crude-CAN	3.6878063	57.387E-6	Canada
compressor-GT-GUS	3.3862361	880.93E-3	CIS
diesel motor-CAN	2.8594155	5.1481E-3	Canada
lignite-ST-rhine	2.7936267	11.228049	Germany
nonmetallic minerals\cement clinker	2.5998986	160.44E-3	Germany
gas-ST-GUS	2.5056800	203.68E-3	CIS
hydro-dam-Tropics	2.4902878	15.957E-3	Tropics
metal\aluminium-CIS	2.4386567	3.3390E-3	CIS
diesel motor-OPEC	2.4037744	268.09E-3	OPEC
oil-heavy-boiler-OPEC	2.4012691	195.13E-3	OPEC
coal-ST-CIS	2.3997465	195.07E-3	CIS
metal\aluminium-D	1.6608861	2.2741E-3	Germany
metal\aluminium-Tropics	1.3819054	1.8921E-3	Tropics
pipeline\gas-CIS	1.3570602	353.04E-3	CIS
compressor-GT-AUS	1.0628576	18.666E-6	Australia
metal\aluminium-AUS	975.46E-3	1.3356E-3	Australia
gas-CC-CAN	933.35E-3	182.08E-6	Canada
gas-boiler-CAN	896.85E-3	2.7713E-3	Canada
coal-ballast-ST-D	805.98E-3	2.4178684	Germany
Xtra-onshore\gas-GUS	788.55E-3	188.23E-3	CIS
oil-heavy-ST-CIS	780.04E-3	63.407E-3	CIS
diesel motor-GUS	744.96E-3	1.5628376	CIS
processing\sinter-D	722.71E-3	115.81E-3	Germany
heat-process-cement-D-coal-100% (end)	683.76E-3	42.163E-3	Germany
metal\aluminium-NOR	650.31E-3	890.39E-6	Norway
compressor-GT-NOR	572.29E-3	150.24E-3	Norway
nonmetallic minerals\CaO-GGR-kiln	566.05E-3	60.659E-3	Germany
processing\gas-AUS	492.31E-3	8.6460E-6	Australia
Xtra-onshore\gas-AUS	492.03E-3	8.6460E-6	Australia

[2] In option 1, energy derived from coal and bagasse in the baseline scenario is 10% and 90% respectively while the proportion of energy derived from woodchips and bagasse is 10% and 90% respectively in option 6 under the mitigation scenario.

coal-boiler-GUS	488.21E-3	668.42E-6	CIS
heat-process-cement-D-lignite-briquettes-rhine-100% (end)	464.72E-3	28.656E-3	Germany
Xtra-onshore-secondary\oil-crude-OPEC	453.33E-3	50.956E-3	OPEC
oil-heavy-boiler-Caribbean	450.23E-3	616.34E-6	Caribbean
oil-heavy-boiler-GUS	437.30E-3	285.70E-3	CIS
gas-boiler-AUS	425.76E-3	392.61E-6	Australia
processing\gas-CIS	378.42E-3	90.329E-3	CIS
Xtra-offshore-secondary\oil-crude-AUS	315.53E-3	1.3029E-6	Australia
gas-boiler-GUS	313.14E-3	43.546E-3	CIS
Xtra-offshore-primary\oil-crude-AUS	310.55E-3	1.2823E-6	Australia
Xtra-mix\coal-CIS	300.58E-3	19.833E-3	CIS
lignite-ST-D-Lausitz-retrofit	278.32E-3	2.5387595	Germany
Xtra-onshore\oil-crude-CIS	266.75E-3	603.17E-3	CIS
compressor-GT-D	254.70E-3	66.259E-3	Germany
coal-ST-D	243.85E-3	10.616065	Germany
coal-boiler-AUS	232.53E-3	318.36E-6	Australia
waste-ST-D	232.50E-3	837.67E-3	Germany
Xtra-offshore\gas-NOR	210.63E-3	55.298E-3	Norway
oil-heavy-boiler-CAN	209.54E-3	527.59E-6	Canada
heat-process-cement-D-oil-heavy-100% (end)	192.61E-3	11.877E-3	Germany
oil-lite-boiler-D	172.27E-3	331.81E-6	Germany
refinery\oil-lite-AUS	167.24E-3	450.67E-9	Australia
diesel motor generic	158.36E-3	36.505E-3	generic
heat-process-CaO-D-gas-100% (end)	154.45E-3	16.551E-3	Germany
propane-boiler-D	153.13E-3	455.96E-3	Germany
coal-ST-CAN	142.07E-3	1.3940E-3	Canada
lignite-ST-D-Leipzig	139.13E-3	988.60E-3	Germany
coal-boiler-Tropics	138.49E-3	189.61E-6	Tropics
gas-CC-D	136.34E-3	4.7543E-3	Germany
processing\gas-NOR	131.65E-3	34.562E-3	Norway
compressor-GT-NL	126.35E-3	32.872E-3	Netherlands
diesel motor-Tropics	124.85E-3	170.92E-6	Tropics
nonmetallic minerals\CaO-kiln	99.898E-3	10.838E-3	Germany
gas-GT-GUS	96.563E-3	23.048E-3	CIS
oil-heavy-boiler-D	95.640E-3	284.78E-3	Germany
Xtra-deep\coal-D-Ballast	93.703E-3	281.12E-3	Germany
oil-lite-boiler-Tropics	93.476E-3	127.98E-6	Tropics
diesel motor-D	91.546E-3	31.617841	Germany
lignite-ST-D-Lausitz	9.928E-3	05.28E-3	Germany
dieselmotor-powerplant-Caribbean	88.412E-3	121.03E-6	Caribbean
train-diesel-freight-BRA	86.320E-3	13.832E-3	Brazil
gas-GT-NOR	76.561E-3	50.961E-3	Norway
Xtra-onshore\gas-NL	76.313E-3	19.855E-3	Netherlands
processing\gas-NL	76.313E-3	19.855E-3	Netherlands
lignite-boiler-FBC-D-rhine	72.178E-3	4.4507E-3	Germany
heat-process-CaO-D-coal-100% (end)	65.746E-3	7.1331E-3	Germany
oi-lite-boiler-AUS	62.599E-3	85.705E-6	Australia
train-diesel-freight-CIS	57.647E-3	78.926E-6	CIS
diesel motor-Caribbean	55.512E-3	75.994E-6	Caribbean
processing\gas-D	51.766E-3	13.467E-3	Germany
Xtra-onshore\gas-D	51.765E-3	13.467E-3	Germany
oil-heavy-boiler-BRA	47.471E-3	7.6069E-3	Brazil
oil-lite-boiler-NOR	42.620E-3	58.351E-6	Norway
compressor-GT-CAN	36.003E-3	57.974E-6	Canada
nonmetallic minerals\clay bricks	34.405E-3	5.5145E-3	Germany
oilgas-boiler-D	32.384E-3	99.069E-3	Germany
pipeline\gas-AUS	32.201E-3	565.12E-9	Australia
gas-boiler-S	28.578E-3	4.5794E-3	Sweden

oil-heavy-boiler-big-generic	28.251E-3	6.5374E-3	generic
gas-boiler-NOR	26.673E-3	20.729E-3	Norway
coal-boiler-FBC-D	23.802E-3	32.586E-6	Germany
gas-ST-D	23.213E-3	1.1188287	Germany
gas-CC-NL	22.269E-3	5.9906E-3	Netherlands
coal-ST-NL	22.061E-3	5.9346E-3	Netherlands
coal-boiler-Caribbean	21.625E-3	29.604E-6	Caribbean
Xtra-offshore-secondary\oil-EU	21.537E-3	64.686E-3	EU
Xtra-offshore-primary\oil-crude-EU	21.197E-3	63.665E-3	EU
waste-ST-CAN	20.644E-3	202.56E-6	Canada
metal\steel-D-EAF-new	17.132E-3	2.7195E-3	Germany
Xtra-onshore\gas-CAN	16.363E-3	26.331E-6	Canada
processing\gas-CAN	16.363E-3	26.349E-6	Canada
diesel motor-EU	16.256E-3	48.822E-3	EU
train-diesel-freight-Tropics	14.696E-3	20.120E-6	Tropics
refinery\oil-heavy-AUS	14.163E-3	58.451E-9	Australia
oil-heavy-ST-CAN	13.367E-3	131.16E-6	Canada
gas-CC-D-East	12.771E-3	574.05E-3	Germany
train-diesel-freight-CAN	12.527E-3	2.0073E-3	Canada
coal-ST-big-generic	11.239E-3	4.6551E-3	generic
gas-boiler-NL	10.526E-3	2.7387E-3	Netherlands
pipeline\gas-NOR	10.396E-3	2.7292E-3	Norway
oil-heavy-ST-D	9.7350E-3	358.48E-3	Germany
heat-process-coking-D-coke	9.1750E-3	1.4699E-3	Germany
gas-GT-D	7.7436E-3	303.98E-3	Germany
chem-inorg\sodium carbonate	6.4822E-3	8.8744E-6	Germany
pipeline\gas-D	5.6126E-3	1.4600E-3	Germany
gas-CC-D-medium	.4583E-3	201.00E-3	Germany
coal-ST-D-coast	4.9937E-3	240.69E-3	Germany
Xtra-surface\coal-CAN	4.9003E-3	48.120E-6	Canada
diesel motor-USA	4.3524E-3	27.467E-3	USA
truck+semi-trailer-highway-EURO 2	4.0734E-3	819.15E-3	local
truck+semi-trailer-highway-1980s	3.9898E-3	802.32E-3	local
Xtra-onshore-primary\crude-oil-generic	3.8762E-3	896.92E-6	generic
oil-heavy-ST-NL	3.5884E-3	965.32E-6	Netherlands
refinery\oil-lite-D	3.4897E-3	10.995E-3	Germany
waste-ST-NL	3.4498E-3	928.04E-6	Netherlands
coal-ST-NOR	3.2590E-3	50.490E-6	Norway
truck+semi-trailer-highway-EURO 1	3.0939E-3	622.17E-3	local
train-diesel-freight-Caribbean	3.0086E-3	4.1187E-6	Caribbean
refinery\oil-heavy-OPEC	2.7410E-3	267.66E-6	OPEC
pipeline\Gas-NL	2.1955E-3	571.19E-6	Netherlands
oil-heavy-ST-small-generic	2.1610E-3	500.03E-6	generic
truck+trailer-highway-1980s-32-40 tons	1.8714E-3	376.36E-3	local
coal-ST-RSA-Matimba	1.6440E-3	7.7955E-3	South Africa
coal-ST-RSA-Duvha	1.5933E-3	7.5550E-3	South Africa
coal-ST-RSA-Kendal	1.5256E-3	7.2340E-3	South Africa
truck-city-1980s-<7.5 tons	1.3075E-3	263.10E-3	local
truck+semi-trailer-rural-1980s	1.2915E-3	259.71E-3	local
truck+semi-trailer-rural-EURO 2	1.1960E-3	240.51E-3	local
truck-rural-1980s-<7.5 tons	1.1540E-3	232.21E-3	local
truck+trailer-highway-1980s-<28 tons	1.0882E-3	218.82E-3	local
coal-ST-RSA-Matla	1.0708E-3	5.0773E-3	South Africa
truck+trailer-highway-1980s-28-32 tons	1.0675E-3	214.66E-3	local
coal-ST-RSA-Tutuka	1.0607E-3	5.0296E-3	South Africa
coal-ST-B	1.0587E-3	513.26E-6	Belgium
truck+trailer-highway-EURO 1-32-40 tons	1.0565E-3	212.48E-3	local
coal-ST-RSA-Lethabo	1.0247E-3	4.8590E-3	South Africa
refinery\oil-heavy-CIS	1.0078E-3	954.46E-6	CIS
Xtra-surface\lignite-D-rhine	981.45E-6	3.2382E-3	Germany

truck+semi-trailer-rural-EURO 1	930.66E-6	187.15E-3	local
oil-distillate-GT-small-generic	918.74E-6	212.59E-6	generic
coal-ST-RSA-Kriel	878.10E-6	4.1637E-3	South Africa
coal-ST-RSA-Hendrina	873.04E-6	4.1397E-3	South Africa
truck-highway-1980s-<7.5 tons	815.16E-6	164.03E-3	local
waste-ST-S	807.20E-6	160.70E-6	Sweden
refinery\oil-lite-CAN	800.57E-6	1.9900E-6	Canada
truck+trailer-highway-EURO 2-32-40 tons	797.17E-6	160.32E-3	local
Xtra-deep\coal-generic	757.47E-6	313.75E-6	generic
coal-ST-S	733.83E-6	146.10E-6	Sweden
truck+semi-trailer-city-1980s	730.97E-6	146.98E-3	local
truck-city-1980s-14-20 tons	710.64E-6	143.00E-3	local
truck+trailer-rural-1980s-32-40 tons	705.23E-6	141.81E-3	local
oil-heavy-ST-S	694.91E-6	138.35E-6	Sweden
truck-rural-1980s-20-28 tons	677.04E-6	136.24E-3	local
pipeline\gas-CAN	654.09E-6	1.0532E-6	Canada
truck-rural-1980s-14-20 tons	648.14E-6	130.42E-3	local
Xtra-offshore\crude-oil-generic	642.78E-6	148.73E-6	generic
truck+semi-trailer-city-EURO 2	639.47E-6	128.58E-3	local
gas-GT-USA	617.27E-6	3.1089E-3	USA
truck-highway-1980s-20-28 tons	613.50E-6	123.45E-3	local
truck-city-1980s-20-28 tons	583.24E-6	117.36E-3	local
Xtra-onshore-tertiary\oil-crude-D	537.17E-6	1.6432E-3	Germany
truck-city-EURO 1-<7.5 tons	533.34E-6	107.32E-3	local
truck+trailer-city-1980s-32-40 tons	512.86E-6	103.12E-3	local
truck+semi-trailer-city-EURO 1	505.42E-6	101.62E-3	local
truck+trailer-rural-1980s-<28 tons	497.48E-6	100.03E-3	local
truck-highway-1980s-14-20 tons	486.06E-6	97.806E-3	local
Xtra-onshore-secondory\crude-oil-generic	484.53E-6	112.11E-6	generic
truck-rural-EURO 1-<7.5 tons	471.06E-6	94.787E-3	local
truck+trailer-highway-EURO 1-28-32 tons	456.91E-6	91.876E-3	local
truck-rural-EURO 1-20-28 tons	429.76E-6	86.477E-3	local
truck+trailer-highway-EURO 1-<28 tons	416.66E-6	83.781E-3	local
truck+trailer-rural-1980s-28-32 tons	398.28E-6	80.086E-3	local
truck+trailer-rural-EURO 1-32-40 tons	397.97E-6	80.023E-3	local
truck-highway-EURO 1-20-28 tons	389.33E-6	78.341E-3	local
truck+trailer-city-1980s-<28 tons	381.77E-6	76.767E-3	local
truck-city-EURO 1-20-28 tons	370.22E-6	74.496E-3	local
truck-city-EURO 2-<7.5 tons	366.80E-6	73.808E-3	local
truck-city-1980s-7.5-14 tons	359.45E-6	72.330E-3	local
truck-rural-1980s-7.5-14 tons	333.67E-6	67.142E-3	local
truck-highway-EURO 1-<7.5 tons	332.65E-6	66.937E-3	local
truck-rural-EURO 2-20-28 tons	332.10E-6	66.826E-3	local
truck+trailer-city-1980s-28-32 tons	332.06E-6	66.771E-3	local
truck-rural-EURO 2-14-20 tons	324.78E-6	65.352E-3	local
truck-rural-EURO 2-<7.5 tons	324.06E-6	65.207E-3	local
wood-ST-small-D	313.16E-6	15.093E-3	Germany
truck+trailer-highway-EURO 2-28-32 tons	306.58E-6	61.646E-3	local
truck-highway-EURO 2-20-28 tons	300.86E-6	60.540E-3	local
truck+trailer-rural-EURO 2-32-40 tons	300.28E-6	60.379E-3	local
truck-city-EURO 1-14-20 tons	299.20E-6	60.206E-3	local
coal-ST-RSA-Arnot	291.08E-6	1.3802E-3	South Africa
truck+trailer-highway-EURO 2-<32 tons	290.66E-6	58.446E-3	local
truck+trailer-city-EURO 1-32-40 tons	289.33E-6	58.179E-3	local
truck-city-EURO 2-20-28 tons	286.07E-6	57.563E-3	local
truck-highway-1980s-7.5-14 tons	274.13E-6	55.160E-3	local
truck-rural-EURO 1-14-20 tons	273.17E-6	54.967E-3	local
oil-naphtha-boiler-D	250.80E-6	49.202E-3	Germany
oil-heavy-boiler-NL	247.93E-6	66.700E-6	Netherlands
oil-heavy-ST-I	242.86E-6	729.31E-6	Italy

truck-highway-EURO 2-<7.5 tons	228.85E-6	46.050E-3	local
gas-GT-S	224.99E-6	44.793E-6	Sweden
waste-ST-USA	219.55E-6	1.0715E-3	USA
truck+trailer-city-EURO 2-32-40 tons	218.30E-6	43.895E-3	local
coal-ST-UK	218.19E-6	655.38E-6	United Kingdom
truck-city-EURO 2-14-20 tons	208.93E-6	42.042E-3	local
truck-highway-EURO 1-14-20 tons	204.78E-6	41.207E-3	local
coal-ST-E	196.03E-6	588.68E-6	Spain
truck+trailer-rural-EURO 1-<28 tons	192.06E-6	38.620E-3	local
gas-CC-DK	191.81E-6	73.843E-6	Denmark
refinery\oil-heavy-D	180.07E-6	233.70E-6	Germany
train-dieselmotor-generic	171.43E-6	49.832E-6	generic
truck+trailer-rural-EURO 1-28-32 tons	170.46E-6	34.275E-3	local
truck+trailer-highway-1970s-<28 tons	163.19E-6	32.815E-3	local
truck-city-1970s-<7.5 tons	160.31E-6	32.258E-3	local
gas-CC-UK	155.24E-6	466.30E-6	United Kingdom
oil-heavy-ST-DK	148.72E-6	57.256E-6	Denmark
truck+trailer-highway-1970s-32-40 tons	148.23E-6	29.811E-3	local
truck+trailer-city-EURO 1-<28 tons	147.47E-6	29.653E-3	local
truck+trailer-city-EURO 1-28-32 tons	142.12E-6	28.577E-3	local
truck-rural-1970s-<7.5 tons	141.45E-6	28.463E-3	local
truck+trailer-highway-1970s-28-32 tons	135.26E-6	27.198E-3	local)
truck+trailer-rural-EURO 2-<28 tons	133.66E-6	26.877E-3	local
truck-city-EURO 1-7.5-14 tons	130.49E-6	26.257E-3	local
coal-ST-UK-with-FGD	128.31E-6	385.40E-6	United Kingdom
Xtra-surface\coal-generic	121.68E-6	50.398E-6	generic
truck-rural-EURO 1-7.5-14 tons	121.17E-6	24.383E-3	local
truck+trailer-rural-EURO 2-28-32 tons	114.37E-6	22.998E-3	local
Xtra-surface\lignite-D-Lausitz	113.93E-6	1.0032E-3	Germany
lignite-ST-GR	109.96E-6	330.21E-6	Greece
truck+trailer-city-EURO 2-<28 tons	102.56E-6	20.624E-3	local
oil-heavy-ST-USA	102.06E-6	498.12E-6	USA
gas-CC-I	101.15E-6	303.75E-6	Italy
truck-highway-1970s-<7.5 tons	99.936E-6	20.109E-3	local
truck-highway-EURO 1-7.5-14 tons	99.557E-6	20.033E-3	local
truck+trailer-city-EURO 2-28-32 tons	95.351E-6	19.173E-3	local
truck+semi-trailer-highway-1970s	94.482E-6	19.000E-3	local
truck-city-EURO 2-7.5-14 tons	92.220E-6	18.557E-3	local
coal-ST-F-Import	90.520E-6	271.83E-6	France
truck-city-1970s-14-20 tons	90.084E-6	18.127E-3	local
truck-rural-EURO 2-7.5-14 tons	85.654E-6	17.236E-3	local
Refinery\diesel-generic	82.920E-6	19.121E-6	generic
coal-ST-I	82.340E-6	247.27E-6	Italy
truck-rural-1970s-14-20 tons	82.103E-6	16.521E-3	local
waste-ST-DK	78.776E-6	30.328E-6	Denmark
truck+trailer-rural-1970s-<28 tons	72.834E-6	14.645E-3	local
truck-highway-EURO 2-7.5-14 tons	70.371E-6	14.160E-3	local
oil-heavy-ST-UK	68.300E-6	205.15E-6	United Kingdom
truck-city-1970s-7.5-14 tons	64.245E-6	12.928E-3	local
coal-ST-SF	62.512E-6	187.76E-6	Finland
truck-highway-1970s-14-20 tons	61.577E-6	12.391E-3	local
truck-rural-1970s-7.5-14 tons	59.617E-6	11.996E-3	local
refinery\oil-heavy-CAN	59.158E-6	174.74E-9	Canada
truck+trailer-rural-1970s-32-40 tons	55.840E-6	11.228E-3	local
truck+trailer-city-1970s-<28 tons	55.774E-6	11.215E-3	local
refinery\liquid gas	50.475E-6	150.44E-6	Germany
truck+trailer-rural-1970s-28-32 tons	50.468E-6	10.148E-3	local
truck-highway-1970s-7.5-14 tons	48.992E-6	9.8582E-3	local
oil-heavy-boiler-S	47.909E-6	9.5379E-6	Sweden
Xtra-surface\lignite-D-Leipzig	42.200E-6	299.88E-6	Germany

truck+trailer-city-1970s-28-32 tons	42.091E-6	8.4637E-3	local
truck+semi-trailer-rural-1970s	41.959E-6	8.4376E-3	local
truck+trailer-city-1970s-32-40 tons	40.618E-6	8.1675E-3	local
coal-ST-P	39.985E-6	120.10E-6	Portugal
truck-rural-1970s-20-28 tons	37.785E-6	7.6031E-3	local
truck-highway-1970s-20-28 tons	34.231E-6	6.8880E-3	local
geothermal-ST-CAN	33.172E-6	325.49E-9	Canada
truck-city-1970s-20-28 tons	32.575E-6	6.5547E-3	local
oil-heavy-ST-E	29.160E-6	87.568E-6	Spain
coal-ST-IRL	27.488E-6	82.560E-6	Ireland
metal\copper-D-primary	27.316E-6	545.43E-6	Germany
truck+semi-trailer-city-1970s	27.230E-6	5.4752E-3	local
gas-CC-E	26.533E-6	79.681E-6	Spain
Xtra-deep\coal-E	26.017E-6	78.126E-6	Spain
waste-ST-SF	24.690E-6	74.156E-6	Finland
coal-ST-A	23.467E-6	70.472E-6	Austria
Xtra-deep\coal-UK	22.994E-6	69.043E-6	United Kingdom
Xtra-onshore-tertiary\oilgas	22.356E-6	69.048E-6	Germany
gas-GT-F	20.634E-6	61.963E-6	France
compressor-GT-USA	20.311E-6	103.82E-6	USA
oil-heavy-ST-GR	19.979E-6	59.998E-6	Greece
oil-heavy-ST-F	19.900E-6	59.760E-6	France
gas-CC-B	18.295E-6	54.941E-6	Belgium
oil-heavy-boiler-I	16.747E-6	50.288E-6	Italy
Refinery\oil-products-generic	15.650E-6	3.6214E-6	generic
waste-ST-UK	14.852E-6	44.610E-6	United Kingdom
oil-heavy-ST-P	14.679E-6	44.087E-6	Portugal
waste-ST-I	14.569E-6	43.752E-6	Italy
truck-rural-East-7.5-14 tons	12.375E-6	2.4901E-3	local
truck+trailer-rural-East-<28 tons	12.332E-6	2.4797E-3	local
refinery\oil-lite-NOR	11.929E-6	16.332E-9	Norway
gas-CC-IRL	11.821E-6	35.505E-6	Ireland
conversion\coke-D	11.159E-6	1.7876E-6	Germany
gas-CC-A	10.780E-6	32.374E-6	Austria
gas-CC-SF	10.325E-6	31.013E-6	Finland
oil-heavy-boiler-DK	10.253E-6	3.9473E-6	Denmark
Truck-very-big-diesel-rural-generic	7.5128E-6	1.8054E-6	generic
oil-heavy-ST-IRL	6.7992E-6	20.422E-6	Ireland
oil-heavy-ST-A	6.5130E-6	19.559E-6	Austria
waste-ST-F	6.1418E-6	18.444E-6	France
truck+trailer-city-East-<28 tons	6.0513E-6	1.2168E-3	local
gas-CC-P	5.7787E-6	17.356E-6	Portugal
Xtra-onshore\gas-USA	5.7115E-6	29.140E-6	USA
processing\gas-USA	5.7055E-6	29.162E-6	USA
waste-ST-E	5.6336E-6	16.918E-6	Spain
truck-city-East-7.5-14 tons	5.5658E-6	1.1200E-3	local
oil-heavy-boiler-UK	4.7192E-6	14.172E-6	United Kingdom
refinery\oil-products-EU	4.5308E-6	13.608E-6	EU
xtra-onshore-secondary\oil-crude-NL	4.3815E-6	1.1787E-6	Netherlands
forestry\dieselmotor-100% (end)	3.5756E-6	216.58E-6	Germany
waste-ST-P	3.4496E-6	10.361E-6	Portugal
oil-heavy-ST-B	3.4297E-6	10.299E-6	Belgium
Xtra-surface\lignite-GR	3.4135E-6	10.250E-6	Greece
geothermal-ST-USA	3.1521E-6	15.384E-6	USA
truck-rural-East-<7.5 tons	2.9713E-6	597.90E-6	local
oil-heavy-ST-SF	2.9571E-6	8.8818E-6	Finland
gas-CC-GR	2.8147E-6	8.4526E-6	Greece
waste-ST-B	2.7799E-6	8.3481E-6	Belgium
Xtra-offshore\gas-DK	2.5833E-6	1.9179E-6	Denmark

coal-cogen-BP-FGD-D-Chem-el (proportional)	2.1867E-6	428.99E-6	Germany
oil-heavy-boiler-E	2.0135E-6	6.0465E-6	Spain
truck+trailer-highway-East-<28 tons	1.9833E-6	398.80E-6	local
Xtra-offshore\gas-UK	1.8054E-6	5.4219E-6	United Kingdom
truck-highway-East-7.5-14 tons	1.7931E-6	360.81E-6	local
processing\gas-DK	1.6146E-6	1.1987E-6	Denmark
oil-heavy-boiler-F	1.5779E-6	4.7385E-6	France
geothermal-ST-I	1.5577E-6	4.6779E-6	Italy
oil-heavy-boiler-GR	1.3845E-6	4.1576E-6	Greece
truck-city-East-<7.5 tons	1.3116E-6	263.93E-6	local
processing\gas-UK	1.1284E-6	3.3887E-6	United Kingdom
oil-heavy-boiler-P	1.0113E-6	3.0373E-6	Portugal
forestry-raising\spruce-abs.dry	984.64E-9	59.642E-6	Germany
refinery\oil-heavy-NL	982.37E-9	264.26E-9	Netherlands
processing\gas-I	762.29E-9	2.2892E-6	Italy
compressor-GT-DK	736.34E-9	283.84E-9	Denmark
coal-cogen-SE-D-Chem-el (proportional)	702.53E-9	137.82E-6	Germany
gas-CC-cogen-big-D-Chem-el (proportional)	690.78E-9	135.52E-6	Germany
waste-ST-A	678.95E-9	2.0389E-6	Austria
compressor-GT-UK	595.85E-9	1.7895E-6	United Kingdom
forestry\2-stroke-ICE-100% (end)	594.60E-9	36.016E-6	Germany
gas-GT-ALG	589.03E-9	1.7693E-6	Algeria
Xtra-onshore\gas-I	571.71E-9	1.7169E-6	Italy
waste-ST-IRL	501.29E-9	1.5056E-6	Ireland
oil-heavy-boiler-IRL	468.44E-9	1.4067E-6	Ireland
oil-heavy-boiler-A	449.02E-9	1.3484E-6	Austria
pipeline\gas-USA	447.54E-9	2.2875E-6	USA
truck-highway-east-<7.5 tons	445.34E-9	89.613E-6	local
compressor-GT-I	407.09E-9	1.2225E-6	Italy
forestry\debarker-100% (end)	403.58E-9	24.446E-6	Germany
Xtra-surface\coal-UK	345.71E-9	1.0380E-6	United Kingdom
wood-logs-boiler-D-wood-manufacturing	337.76E-9	20.459E-6	Germany
waste-ST-GR	321.39E-9	965.14E-9	Greece
gas-boiler-DK	260.54E-9	193.43E-9	Denmark
oil-heavy-boiler-B	236.29E-9	709.51E-9	Belgium
oil-heavy-boiler-SF	203.73E-9	611.90E-9	Finland
compressor-GT-F	196.70E-9	590.71E-9	France
refinery\oil-heavy-S	196.69E-9	39.159E-9	Sweden
diesel motor-UK	187.79E-9	564.58E-9	United Kingdom
gas-boiler-UK	182.08E-9	546.82E-9	United Kingdom
Xtra-onshore\gas-ALG	165.70E-9	497.66E-9	Algeria
processing\gas-ALG	165.70E-9	497.66E-9	Algeria
Xtra-offshore\gas-IRL	137.47E-9	412.90E-9	Ireland
xtra-onshore-secondary\oil-crude-I	122.57E-9	368.05E-9	Italy
gas-boiler-I	118.62E-9	356.20E-9	Italy
compressor-GT-E	106.66E-9	320.31E-9	Spain
processing\gas-IRL	85.920E-9	258.06E-9	Ireland
refinery\oil-heavy-I	68.698E-9	206.30E-9	Italy
xtra-onshore-secondary\oil-crude-GR	65.563E-9	196.88E-9	Greece
compressor-GT-IRL	45.372E-9	136.27E-9	Ireland
compressor-GT-A	43.347E-9	130.17E-9	Austria
refinery\oil-heavy-DK	42.096E-9	16.206E-9	Denmark
compressor-GT-SF	39.584E-9	118.89E-9	Finland
xtra-onshore-secondary\oil-crude-E	36.795E-9	110.49E-9	Spain
compressor-GT-ALG	36.103E-9	108.42E-9	Algeria
forestry\helicopter-100% (end)	28.498E-9	1.7262E-6	Germany
compressor-GT-P	23.230E-9	69.771E-9	Portugal
geothermal-ST-P	19.947E-9	59.912E-9	Portugal

refinery\oil-heavy-UK	19.375E-9	58.187E-9	United Kingdom
processing\gas-A	17.857E-9	53.626E-9	Austria
gas-boiler-IRL	13.865E-9	41.642E-9	Ireland
Xtra-onshore\gas-A	13.393E-9	40.220E-9	Austria
pipeline\gas-DK	13.376E-9	5.1560E-9	Denmark
gas-boiler-ALG	11.674E-9	35.059E-9	Algeria
pipeline\gas-UK	10.824E-9	32.506E-9	United Kingdom
compressor-GT-GR	10.791E-9	32.405E-9	Greece
pipeline\gas-I	8.9700E-9	26.937E-9	Italy
refinery\oil-heavy-E	8.2494E-9	24.773E-9	Spain
refinery\oil-heavy-F	5.6839E-9	17.069E-9	France
refinery\oil-heavy-GR	5.6534E-9	16.977E-9	Greece
plastics\plastic-generic	4.5599E-9	1.0957E-9	generic
refinery\oil-heavy-P	4.1519E-9	12.470E-9	Portugal
pipeline\gas-F	3.5732E-9	10.730E-9	France
gas-boiler-A	2.7787E-9	8.3445E-9	Austria
liquefaction\LNG-ALG	2.5300E-9	7.5978E-9	Algeria
xtra-onshore-tertiary\oil-crude-F	2.4645E-9	7.4003E-9	France
pipeline\gas-E	2.3503E-9	7.0580E-9	Spain
refinery\oil-heavy-IRL	1.8598E-9	5.5849E-9	Ireland
refinery\oil-heavy-A	1.8435E-9	5.5359E-9	Austria
pipeline\gas-B	1.5050E-9	4.5197E-9	Belgium
pipeline\gas-NL->B	1.5050E-9	4.5194E-9	Netherlands
refinery\oil-heavy-B	70.1E-12	.9132E-9	Belgium
pipeline\gas-A	955.1E-12	2.8683E-9	Austria
pipeline\gas-ALG	874.3E-12	2.6255E-9	Algeria
refinery\oil-heavy-SF	836.4E-12	2.5122E-9	Finland
pipeline\gas-IRL	824.2E-12	2.4755E-9	Ireland
pipeline\gas-SF	719.1E-12	2.1597E-9	Finland
pipeline\gas-P	511.9E-12	1.5374E-9	Portugal
pipeline\gas-GR	196.0E-12	588.6E-12	Greece
pipeline\gas-D-export	71.64E-12	215.1E-12	Germany
wood-chips-heat plant-D 1 MW'NSW	0.0000000	33.134172	Australia
Xtra-plantation\wood-short-rotation-D	0.0000000	53.048128	Germany
refinery\oil-heavy-USA	31.503E-9	658.83E-9	USA
Xtra-onshore-tertiary\oil-crude-USA	181.69E-9	1.6375E-6	USA
refinery\oil-lite-USA	872.44E-9	7.4830E-6	USA
Xtra-surface\lignite-PL	1.2595E-6	116.01E-9	Poland
gas-boiler-USA	2.5106E-6	33.081E-6	USA
Xtra-offshore-primary\oil-crude-USA	14.167E-6	127.69E-6	USA
Xtra-offshore-secondary\oil-crude-USA	14.394E-6	129.73E-6	USA
oilgas-boiler-USA	78.764E-6	709.89E-6	USA
oil-heavy-boiler-USA	220.31E-6	1.9844E-3	USA
coal-ST-RSA	3.3871E-3	10.879E-6	South Africa
lignite-ST-big-PL	4.0747E-3	375.31E-6	Poland
coal-ST-PL-retrofit	5.5236E-3	508.76E-6	Poland
Xtra-deep\coal-PL	6.4356E-3	604.53E-6	Poland
train-diesel-freight-USA	7.5466E-3	626.64E-6	USA
coal-ST-USA	10.751E-3	15.037E-3	USA
ship-freight-D-domestic	17.454E-3	10.665E-3	Germany
Xtra-deep\coal-RSA	38.510E-3	123.76E-6	South Africa
Xtra-mix\coal-USA	67.101E-3	5.5816E-3	USA
Xtra-deep\coal-D	143.13E-3	1.0762528	Germany
coal-cogen-SE-D-Chem-th (proportional)	771.01E-3	164.15E-3	Germany
gas-CC-cogen-big-D-Chem-th (proportional)-	3.2103066	683.49E-3	Germany
coal-cogen-BP-FGD-D-Chem-th (proportional)	12.834754	2.7325704	Germany

Appendix 2. Comparison of greenhouse gas emissions in option 2 and option 7[3]

Process	Greenhouse gas emissions (tonnes in CO_2 equivalents) Option 1	Option 6	Location
Sum	198.525E3	4.30917E3	
coal-boiler-AUS'NSW	185.717E3	0.0000000	Australia
Xtra-surface\coal-AUS	5.68227E3	519.32E-6	Australia
bagasse-ST-FJ-FSC'NSW	3.91055E3	3.91055E3	Fiji
coal-ST-AUS	1.29875E3	13.658E-3	Australia
train-diesel-freight-AUS	723.23579	2.8069E-3	Australia
diesel motor-AUS	482.53151	277.56E-6	Australia
chem-inorg\nitric acid	192.32775	40.715768	Germany
gas-GT-AUS	110.70752	1.1652E-3	Australia
oil-heavy-boiler-AUS	88.422294	248.15E-6	Australia
chem-inorg\ammonia	77.446587	16.428007	Germany
waste-ST-AUS	45.784927	481.48E-6	Australia
gas-boiler-D	37.254979	8.4874801	Germany
blasting (ANFO)	18.397636	232.92E-6	generic
oil-heavy-ST-AUS	18.351703	192.99E-6	Australia
metal\pig-iron-D	13.839600	2.2176666	Germany
xtra-onshore-primary\oil-crude-OPEC	12.502143	1.4052999	OPEC
ship (ocean)	10.267111	1.1587719	generic
Xtra-offshore-secondary\oil-CAN	7.4938476	116.61E-6	Canada
Xtra-offshore-primary\oil-crude-CAN	7.3756126	114.77E-6	Canada
compressor-GT-GUS	6.7724722	1.7618685	CIS
diesel motor-CAN	5.7188311	10.296E-3	Canada
lignite-ST-rhine	5.5872533	22.456097	Germany
nonmetallic minerals\cement clinker	5.1997972	320.89E-3	Germany
gas-ST-GUS	5.0113600	407.35E-3	CIS
hydro-dam-Tropics	4.9805755	31.915E-3	Tropics
metal\aluminium-CIS	4.8773133	6.6780E-3	CIS
diesel motor-OPEC	4.8075488	536.19E-3	OPEC
oil-heavy-boiler-OPEC	4.8025382	390.27E-3	OPEC
coal-ST-CIS	4.7994930	390.13E-3	CIS
metal\aluminium-D	3.3217721	4.5481E-3	Germany
metal\aluminium-Tropics	2.7638109	3.7842E-3	Tropics
pipeline\gas-CIS	2.7141205	706.07E-3	CIS
compressor-GT-AUS	2.1257152	37.331E-6	Australia
metal\aluminium-AUS	1.9509253	2.6712E-3	Australia
gas-CC-CAN	1.8666963	364.16E-6	Canada
gas-boiler-CAN	1.7936961	5.5427E-3	Canada
coal-ballast-ST-D	1.6119673	4.8357368	Germany
Xtra-onshore\gas-GUS	1.5771056	376.45E-3	CIS
oil-heavy-ST-CIS	1.5600896	126.81E-3	CIS
diesel motor-GUS	1.4899274	3.1256753	CIS
processing\sinter-D	1.4454284	231.62E-3	Germany
heat-process-cement-D-coal-100% (end)	1.3675175	84.325E-3	Germany
metal\aluminium-NOR	1.3006169	1.7808E-3	Norway
compressor-GT-NOR	1.1445810	300.49E-3	Norway
nonmetallic minerals\CaO-GGR-kiln	1.1321019	121.32E-3	Germany
processing\gas-AUS	984.63E-3	17.292E-6	Australia

[3] In option 1, energy derived from coal and bagasse in the baseline scenario is 20% and 80% respectively while the proportion of energy derived from woodchips and bagasse is 20% and 80% respectively in option 6 under the mitigation scenario.

Xtra-onshore\gas-AUS	984.06E-3	17.292E-6	Australia
coal-boiler-GUS	976.42E-3	1.3368E-3	CIS
heat-process-cement-D-lignite-briquettes-rhine-100% (end)	929.43E-3	57.312E-3	Germany
Xtra-onshore-secondary\oil-crude-OPEC	906.65E-3	101.91E-3	OPEC
oil-heavy-boiler-Caribbean	900.45E-3	1.2327E-3	Caribbean
oil-heavy-boiler-GUS	874.59E-3	571.40E-3	CIS
gas-boiler-AUS	851.53E-3	785.22E-6	Australia
processing\gas-CIS	756.85E-3	180.66E-3	CIS
Xtra-offshore-secondary\oil-crude-AUS	631.06E-3	2.6058E-6	Australia
gas-boiler-GUS	626.29E-3	87.093E-3	CIS
Xtra-offshore-primary\oil-crude-AUS	621.11E-3	2.5647E-6	Australia
Xtra-mix\coal-CIS	601.15E-3	39.665E-3	CIS
lignite-ST-D-Lausitz-retrofit	556.65E-3	5.0775190	Germany
Xtra-onshore\oil-crude-CIS	533.49E-3	1.2063477	CIS
compressor-GT-D	509.40E-3	132.52E-3	Germany
coal-ST-D	487.69E-3	21.232130	Germany
coal-boiler-AUS	465.07E-3	636.73E-6	Australia
waste-ST-D	465.00E-3	1.6753489	Germany
Xtra-offshore\gas-NOR	421.27E-3	110.60E-3	Norway
oil-heavy-boiler-CAN	419.07E-3	1.0552E-3	Canada
heat-process-cement-D-oil-heavy-100% (end)	385.22E-3	23.754E-3	Germany
oil-lite-boiler-D	344.55E-3	663.62E-6	Germany
refinery\oil-lite-AUS	334.48E-3	901.33E-9	Australia
diesel motor generic	316.72E-3	73.010E-3	generic
heat-process-CaO-D-gas-100% (end)	308.90E-3	33.102E-3	Germany
propane-boiler-D	306.26E-3	911.92E-3	Germany
coal-ST-CAN	284.14E-3	2.7880E-3	Canada
lignite-ST-D-Leipzig	278.25E-3	1.9771904	Germany
coal-boiler-Tropics	276.99E-3	379.23E-6	Tropics
gas-CC-D	272.69E-3	9.5086E-3	Germany
processing\gas-NOR	263.30E-3	69.124E-3	Norway
compressor-GT-NL	252.69E-3	65.744E-3	Netherlands
diesel motor-Tropics	249.70E-3	341.84E-6	Tropics
nonmetallic minerals\CaO-kiln	199.80E-3	21.677E-3	Germany
gas-GT-GUS	193.13E-3	46.095E-3	CIS
oil-heavy-boiler-D	191.28E-3	569.56E-3	Germany
Xtra-deep\coal-D-Ballast	187.41E-3	562.23E-3	Germany
oil-lite-boiler-Tropics	186.95E-3	255.96E-6	Tropics
diesel motor-D	183.09E-3	63.235682	Germany
lignite-ST-D-Lausitz	179.86E-3	1.4105636	Germany
dieselmotor-powerplant-Caribbean	176.82E-3	242.07E-6	Caribbean
train-diesel-freight-BRA	172.64E-3	27.664E-3	Brazil
gas-GT-NOR	153.12E-3	101.92E-3	Norway
Xtra-onshore\gas-NL	152.63E-3	39.710E-3	Netherlands
processing\gas-NL	152.63E-3	39.710E-3	Netherlands
lignite-boiler-FBC-D-rhine	144.36E-3	8.9014E-3	Germany
heat-process-CaO-D-coal-100% (end)	131.49E-3	14.266E-3	Germany
oi-lite-boiler-AUS	125.20E-3	171.41E-6	Australia
train-diesel-freight-CIS	115.29E-3	157.85E-6	CIS
diesel motor-Caribbean	111.02E-3	151.99E-6	Caribbean
processing\gas-D	103.53E-3	26.933E-3	Germany
Xtra-onshore\gas-D	103.53E-3	26.933E-3	Germany
oil-heavy-boiler-BRA	94.943E-3	15.214E-3	Brazil
oil-lite-boiler-NOR	85.240E-3	116.70E-6	Norway
compressor-GT-CAN	72.005E-3	115.95E-6	Canada
nonmetallic minerals\clay bricks	68.811E-3	11.029E-3	Germany
oilgas-boiler-D	64.768E-3	198.14E-3	Germany
pipeline\gas-AUS	64.401E-3	1.1302E-6	Australia

gas-boiler-S	57.157E-3	9.1589E-3	Sweden
oil-heavy-boiler-big-generic	56.502E-3	13.075E-3	generic
gas-boiler-NOR	53.346E-3	41.458E-3	Norway -
coal-boiler-FBC-D	47.605E-3	65.171E-6	Germany
gas-ST-D	46.427E-3	2.2376574	Germany
gas-CC-NL	44.538E-3	11.981E-3	Netherlands
coal-ST-NL	44.122E-3	11.869E-3	Netherlands
coal-boiler-Caribbean	43.251E-3	59.209E-6	Caribbean
Xtra-offshore-secondary\oil-EU	43.074E-3	129.37E-3	EU
Xtra-offshore-primary\oil-crude-EU	42.394E-3	127.33E-3	EU
waste-ST-CAN	41.288E-3	405.12E-6	Canada
metal\steel-D-EAF-new	34.264E-3	5.4390E-3	Germany
Xtra-onshore\gas-CAN	32.727E-3	52.663E-6	Canada
processing\gas-CAN	32.727E-3	52.699E-6	Canada
diesel motor-EU	32.512E-3	97.645E-3	EU
train-diesel-freight-Tropics	29.392E-3	40.239E-6	Tropics
refinery\oil-heavy-AUS	28.326E-3	116.90E-9	Australia
oil-heavy-ST-CAN	26.733E-3	262.31E-6	Canada
gas-CC-D-East	25.542E-3	1.1481014	Germany
train-diesel-freight-CAN	25.054E-3	4.0147E-3	Canada
coal-ST-big-generic	22.478E-3	9.3102E-3	generic
gas-boiler-NL	21.052E-3	5.4774E-3	Netherlands
pipeline\gas-NOR	20.792E-3	5.4585E-3	Norway
oil-heavy-ST-D	19.470E-3	716.97E-3	Germany
heat-process-coking-D-coke	18.350E-3	2.9397E-3	Germany
gas-GT-D	15.487E-3	607.96E-3	Germany
chem-inorg\sodium carbonate	12.964E-3	17.749E-6	Germany
pipeline\gas-D	11.225E-3	2.9200E-3	Germany
gas-CC-D-medium	10.917E-3	401.99E-3	Germany
coal-ST-D-coast	9.9875E-3	481.37E-3	Germany
Xtra-surface\coal-CAN	9.8006E-3	96.240E-6	Canada
diesel motor-USA	8.7047E-3	54.934E-3	USA
truck+semi-trailer-highway-EURO 2	8.1469E-3	1.6382918	local
truck+semi-trailer-highway-1980s	7.9795E-3	1.6046338	local
Xtra-onshore-primary\crude-oil-generic	7.7524E-3	1.7938E-3	generic
oil-heavy-ST-NL	7.1769E-3	1.9306E-3	Netherlands
refinery\oil-lite-D	6.9793E-3	21.990E-3	Germany
waste-ST-NL	6.8997E-3	1.8561E-3	Netherlands
coal-ST-NOR	6.5179E-3	100.98E-6	Norway
truck+semi-trailer-highway-EURO 1	6.1878E-3	1.2443310	local
train-diesel-freight-Caribbean	6.0172E-3	8.2374E-6	Caribbean
refinery\oil-heavy-OPEC	5.4821E-3	535.31E-6	OPEC
pipeline\Gas-NL	4.3909E-3	1.1424E-3	Netherlands
oil-heavy-ST-small-generic	4.3219E-3	1.0001E-3	generic
truck+trailer-highway-1980s-32-40 tons	3.7427E-3	752.71E-3	local
coal-ST-RSA-Matimba	3.2881E-3	15.591E-3	South Africa
coal-ST-RSA-Duvha	3.1866E-3	15.110E-3	South Africa
coal-ST-RSA-Kendal	3.0512E-3	14.468E-3	South Africa
truck-city-1980s-<7.5 tons	2.6150E-3	526.20E-3	local
truck+semi-trailer-rural-1980s	2.5830E-3	519.42E-3	local
truck+semi-trailer-rural-EURO 2	2.3920E-3	481.01E-3	local
truck-rural-1980s-<7.5 tons	2.3080E-3	464.43E-3	local
truck+trailer-highway-1980s-<28 tons	2.1764E-3	437.64E-3	local
coal-ST-RSA-Matla	2.1416E-3	10.155E-3	South Africa
truck+trailer-highway-1980s-28-32 tons	2.1351E-3	429.32E-3	local
coal-ST-RSA-Tutuka	2.1214E-3	10.059E-3	South Africa
coal-ST-B	2.1174E-3	1.0265E-3	Belgium
truck+trailer-highway-EURO 1-32-40 tons	2.1130E-3	424.96E-3	local
coal-ST-RSA-Lethabo	2.0495E-3	9.7181E-3	South Africa
refinery\oil-heavy-CIS	2.0156E-3	1.9089E-3	CIS

Xtra-surface\lignite-D-rhine	1.9629E-3	6.4764E-3	Germany
truck+semi-trailer-rural-EURO 1	1.8613E-3	374.30E-3	local
oil-distillate-GT-small-generic	1.8375E-3	425.17E-6	generic
coal-ST-RSA-Kriel	1.7562E-3	8.3274E-3	South Africa
coal-ST-RSA-Hendrina	1.7461E-3	8.2794E-3	South Africa
truck-highway-1980s-<7.5 tons	1.6303E-3	328.06E-3	local
waste-ST-S	1.6144E-3	321.41E-6	Sweden
refinery\oil-lite-CAN	1.6011E-3	3.9800E-6	Canada
truck+trailer-highway-EURO 2-32-40 tons	1.5943E-3	320.64E-3	local
Xtra-deep\coal-generic	1.5149E-3	627.49E-6	generic
coal-ST-S	1.4677E-3	292.19E-6	Sweden
truck+semi-trailer-city-1980s	1.4619E-3	293.95E-3	local
truck-city-1980s-14-20 tons	1.4213E-3	285.99E-3	local
truck+trailer-rural-1980s-32-40 tons	1.4105E-3	283.61E-3	local
oil-heavy-ST-S	1.3898E-3	276.70E-6	Sweden
truck-rural-1980s-20-28 tons	1.3541E-3	272.47E-3	local
pipeline\gas-CAN	1.3082E-3	2.1063E-6	Canada
truck-rural-1980s-14-20 tons	1.2963E-3	260.84E-3	local
Xtra-offshore\crude-oil-generic	1.2856E-3	297.46E-6	generic
truck+semi-trailer-city-EURO 2	1.2789E-3	257.16E-3	local
gas-GT-USA	1.2345E-3	6.2179E-3	USA
truck-highway-1980s-20-28 tons	1.2270E-3	246.90E-3	local
truck-city-1980s-20-28 tons	1.1665E-3	234.72E-3	local
Xtra-onshore-tertiary\oil-crude-D	1.0743E-3	3.2864E-3	Germany
truck-city-EURO 1-<7.5 tons	1.0667E-3	214.64E-3	local
truck+trailer-city-1980s-32-40 tons	1.0257E-3	206.25E-3	local
truck+semi-trailer-city-EURO 1	1.0108E-3	203.25E-3	local
truck+trailer-rural-1980s-<28 tons	994.97E-6	200.07E-3	local
truck-highway-1980s-14-20 tons	972.12E-6	195.61E-3	local
Xtra-onshore-secondory\crude-oil-generic	969.05E-6	224.23E-6	generic
truck-rural-EURO 1-<7.5 tons	942.11E-6	189.57E-3	local
truck+trailer-highway-EURO 1-28-32 tons	913.82E-6	183.75E-3	local
truck-rural-EURO 1-20-28 tons	859.52E-6	172.95E-3	local
truck+trailer-highway-EURO 1-<28 tons	833.32E-6	167.56E-3	local
truck+trailer-rural-1980s-28-32 tons	796.56E-6	160.17E-3	local
truck+trailer-rural-EURO 1-32-40 tons	795.93E-6	160.05E-3	local
truck-highway-EURO 1-20-28 tons	778.65E-6	156.68E-3	local
truck+trailer-city-1980s-<28 tons	763.55E-6	153.53E-3	local
truck-city-EURO 1-20-28 tons	740.44E-6	148.99E-3	local
truck-city-EURO 2-<7.5 tons	733.59E-6	147.62E-3	local
truck-city-1980s-7.5-14 tons	718.91E-6	144.66E-3	local
truck-rural-1980s-7.5-14 tons	667.34E-6	134.28E-3	local
truck-highway-EURO 1-<7.5 tons	665.30E-6	133.87E-3	local
truck-rural-EURO 2-20-28 tons	664.21E-6	133.65E-3	local
truck+trailer-city-1980s-28-32 tons	664.12E-6	133.54E-3	local
truck-rural-EURO 2-14-20 tons	649.55E-6	130.70E-3	local
truck-rural-EURO 2-<7.5 tons	648.11E-6	130.41E-3	local
wood-ST-small-D	626.31E-6	30.187E-3	Germany
truck+trailer-highway-EURO 2-28-32 tons	613.15E-6	123.29E-3	local
truck-highway-EURO 2-20-28 tons	601.72E-6	121.08E-3	local
truck+trailer-rural-EURO 2-32-40 tons	600.55E-6	120.76E-3	local
truck-city-EURO 1-14-20 tons	598.40E-6	120.41E-3	local
coal-ST-RSA-Arnot	582.15E-6	2.7604E-3	South Africa
truck+trailer-highway-EURO 2-<32 tons	581.32E-6	116.89E-3	local
truck+trailer-city-EURO 1-32-40 tons	578.67E-6	116.36E-3	local
truck-city-EURO 2-20-28 tons	572.13E-6	115.13E-3	local
truck-highway-1980s-7.5-14 tons	548.25E-6	110.32E-3	local
truck-rural-EURO 1-14-20 tons	546.33E-6	109.93E-3	local
oil-naphtha-boiler-D	501.60E-6	98.404E-3	Germany
oil-heavy-boiler-NL	495.87E-6	133.40E-6	Netherlands

oil-heavy-ST-I	485.72E-6	1.4586E-3	Italy
truck-highway-EURO 2-<7.5 tons	457.71E-6	92.101E-3	local
gas-GT-S	449.99E-6	89.586E-6	Sweden
waste-ST-USA	439.10E-6	2.1430E-3	USA
truck+trailer-city-EURO 2-32-40 tons	436.59E-6	87.790E-3	local
coal-ST-UK	436.38E-6	1.3108E-3	United Kingdom
truck-city-EURO 2-14-20 tons	417.87E-6	84.085E-3	local
truck-highway-EURO 1-14-20 tons	409.57E-6	82.414E-3	local
coal-ST-E	392.06E-6	1.1774E-3	Spain
truck+trailer-rural-EURO 1-<28 tons	384.12E-6	77.240E-3	local
gas-CC-DK	383.62E-6	147.69E-6	Denmark
refinery\oil-heavy-D	360.14E-6	467.39E-6	Germany
train-dieselmotor-generic	342.86E-6	99.664E-6	generic
truck+trailer-rural-EURO 1-28-32 tons	340.91E-6	68.550E-3	local
truck+trailer-highway-1970s-<28 tons	326.39E-6	65.629E-3	local
truck-city-1970s-<7.5 tons	320.62E-6	64.515E-3	local
gas-CC-UK	310.49E-6	932.61E-6	United Kingdom
oil-heavy-ST-DK	297.45E-6	114.51E-6	Denmark
truck+trailer-highway-1970s-32-40 tons	296.46E-6	59.622E-3	local
truck+trailer-city-EURO 1-<28 tons	294.94E-6	59.306E-3	local
truck+trailer-city-EURO 1-28-32 tons	284.23E-6	57.154E-3	local
truck-rural-1970s-<7.5 tons	282.90E-6	56.926E-3	local
truck+trailer-highway-1970s-28-32 tons	270.52E-6	54.396E-3	local
truck+trailer-rural-EURO 2-<28 tons	267.32E-6	53.753E-3	local
truck-city-EURO 1-7.5-14 tons	260.98E-6	52.514E-3	local
coal-ST-UK-with-FGD	256.62E-6	770.80E-6	United Kingdom
Xtra-surface\coal-generic	243.35E-6	100.80E-6	generic
truck-rural-EURO 1-7.5-14 tons	242.35E-6	48.766E-3	local
truck+trailer-rural-EURO 2-28-32 tons	228.74E-6	45.996E-3	local
Xtra-surface\lignite-D-Lausitz	227.86E-6	2.0064E-3	Germany
lignite-ST-GR	219.92E-6	660.41E-6	Greece
truck+trailer-city-EURO 2-<28 tons	205.13E-6	41.247E-3	local
oil-heavy-ST-USA	204.13E-6	996.24E-6	USA
gas-CC-I	202.30E-6	607.50E-6	Italy
truck-highway-1970s-<7.5 tons	199.87E-6	40.219E-3	local
truck-highway-EURO 1-7.5-14 tons	199.11E-6	40.066E-3	local
truck+trailer-city-EURO 2-28-32 tons	190.70E-6	38.346E-3	local
truck+semi-trailer-highway-1970s	188.96E-6	38.000E-3	local
truck-city-EURO 2-7.5-14 tons	184.44E-6	37.114E-3	local
coal-ST-F-Import	181.04E-6	543.67E-6	France
truck-city-1970s-14-20 tons	180.17E-6	36.254E-3	local
truck-rural-EURO 2-7.5-14 tons	171.31E-6	34.471E-3	local
Refinery\diesel-generic	165.84E-6	38.241E-6	generic
coal-ST-I	164.68E-6	494.54E-6	Italy
truck-rural-1970s-14-20 tons	164.21E-6	33.042E-3	local
waste-ST-DK	157.55E-6	60.655E-6	Denmark
truck+trailer-rural-1970s-<28 tons	145.67E-6	29.291E-3	local
truck-highway-EURO 2-7.5-14 tons	140.74E-6	28.320E-3	local
oil-heavy-ST-UK	136.60E-6	410.31E-6	United Kingdom
truck-city-1970s-7.5-14 tons	128.49E-6	25.855E-3	local
coal-ST-SF	125.02E-6	375.51E-6	Finland
truck-highway-1970s-14-20 tons	123.15E-6	24.781E-3	local
truck-rural-1970s-7.5-14 tons	119.23E-6	23.992E-3	local
refinery\oil-heavy-CAN	118.32E-6	349.48E-9	Canada
truck+trailer-rural-1970s-32-40 tons	111.68E-6	22.456E-3	local
truck+trailer-city-1970s-<28 tons	111.55E-6	22.430E-3	local
refinery\liquid gas	100.95E-6	300.89E-6	Germany
truck+trailer-rural-1970s-28-32 tons	100.94E-6	20.296E-3	local
truck-highway-1970s-7.5-14 tons	97.983E-6	19.716E-3	local
oil-heavy-boiler-S	95.817E-6	19.076E-6	Sweden

Xtra-surface\lignite-D-Leipzig	84.401E-6	599.77E-6	Germany
truck+trailer-city-1970s-28-32 tons	84.182E-6	16.927E-3	local
truck+semi-trailer-rural-1970s	83.917E-6	16.875E-3	local
truck+trailer-city-1970s-32-40 tons	81.237E-6	16.335E-3	local
coal-ST-P	79.970E-6	240.19E-6	Portugal
truck-rural-1970s-20-28 tons	75.569E-6	15.206E-3	local
truck-highway-1970s-20-28 tons	68.461E-6	13.776E-3	local
geothermal-ST-CAN	66.344E-6	650.98E-9	Canada
truck-city-1970s-20-28 tons	65.149E-6	13.109E-3	local
oil-heavy-ST-E	58.320E-6	175.14E-6	Spain
coal-ST-IRL	54.975E-6	165.12E-6	Ireland
metal\copper-D-primary	54.633E-6	1.0909E-3	Germany
truck+semi-trailer-city-1970s	54.461E-6	10.950E-3	local
gas-CC-E	53.067E-6	159.36E-6	Spain
Xtra-deep\coal-E	52.033E-6	156.25E-6	Spain
waste-ST-SF	49.379E-6	148.31E-6	Finland
coal-ST-A	46.934E-6	140.94E-6	Austria
Xtra-deep\coal-UK	45.988E-6	138.09E-6	United Kingdom
Xtra-onshore-tertiary\oilgas	44.711E-6	138.10E-6	Germany
gas-GT-F	41.267E-6	123.93E-6	France
compressor-GT-USA	40.622E-6	207.63E-6	USA
oil-heavy-ST-GR	39.958E-6	120.00E-6	Greece
oil-heavy-ST-F	39.800E-6	119.52E-6	France
gas-CC-B	36.590E-6	109.88E-6	Belgium
oil-heavy-boiler-I	33.494E-6	100.58E-6	Italy
Refinery\oil-products-generic	31.299E-6	7.2428E-6	generic
waste-ST-UK	29.703E-6	89.220E-6	United Kingdom
oil-heavy-ST-P	29.357E-6	88.175E-6	Portugal
waste-ST-I	29.139E-6	87.504E-6	Italy
truck-rural-East-7.5-14 tons	24.750E-6	4.9802E-3	local
truck+trailer-rural-East-<28 tons	24.663E-6	4.9593E-3	local
refinery\oil-lite-NOR	23.859E-6	32.665E-9	Norway
gas-CC-IRL	23.642E-6	71.010E-6	Ireland
conversion\coke-D	22.317E-6	3.5753E-6	Germany
gas-CC-A	21.561E-6	64.747E-6	Austria
gas-CC-SF	20.651E-6	62.025E-6	Finland
oil-heavy-boiler-DK	20.506E-6	7.8947E-6	Denmark
Truck-very-big-diesel-rural-generic	15.026E-6	3.6108E-6	generic
oil-heavy-ST-IRL	13.598E-6	40.843E-6	Ireland
oil-heavy-ST-A	13.026E-6	39.118E-6	Austria
waste-ST-F	12.284E-6	36.888E-6	France
truck+trailer-city-East-<28 tons	12.103E-6	2.4336E-3	local
gas-CC-P	11.557E-6	34.713E-6	Portugal
Xtra-onshore\gas-USA	11.423E-6	58.280E-6	USA
processing\gas-USA	11.411E-6	58.325E-6	USA
waste-ST-E	11.267E-6	33.836E-6	Spain
truck-city-East-7.5-14 tons	11.132E-6	2.2399E-3	local
oil-heavy-boiler-UK	9.4384E-6	28.345E-6	United Kingdom
refinery\oil-products-EU	9.0617E-6	27.215E-6	EU
xtra-onshore-secondary\oil-crude-NL	8.7629E-6	2.3574E-6	Netherlands
forestry\dieselmotor-100% (end)	7.1512E-6	433.16E-6	Germany
waste-ST-P	6.8992E-6	20.722E-6	Portugal
oil-heavy-ST-B	6.8593E-6	20.599E-6	Belgium
Xtra-surface\lignite-GR	6.8269E-6	20.500E-6	Greece
geothermal-ST-USA	6.3042E-6	30.767E-6	USA
truck-rural-East-<7.5 tons	5.9427E-6	1.1958E-3	local
oil-heavy-ST-SF	5.9142E-6	17.764E-6	Finland
gas-CC-GR	5.6294E-6	16.905E-6	Greece
waste-ST-B	5.5598E-6	16.696E-6	Belgium
Xtra-offshore\gas-DK	5.1666E-6	3.8357E-6	Denmark

coal-cogen-BP-FGD-D-Chem-el (proportional)	4.3734E-6	857.98E-6	Germany
oil-heavy-boiler-E	4.0270E-6	12.093E-6	Spain
truck+trailer-highway-East-<28 tons	3.9666E-6	797.59E-6	local
Xtra-offshore\gas-UK	3.6108E-6	10.844E-6	United Kingdom
truck-highway-East-7.5-14 tons	3.5861E-6	721.61E-6	local
processing\gas-DK	3.2291E-6	2.3973E-6	Denmark
oil-heavy-boiler-F	3.1558E-6	9.4771E-6	France
geothermal-ST-I	3.1155E-6	9.3559E-6	Italy
oil-heavy-boiler-GR	2.7690E-6	8.3152E-6	Greece
truck-city-East-<7.5 tons	2.6233E-6	527.86E-6	local
processing\gas-UK	2.2567E-6	6.7774E-6	United Kingdom
oil-heavy-boiler-P	2.0226E-6	6.0746E-6	Portugal
forestry-raising\spruce-abs.dry	1.9693E-6	119.28E-6	Germany
refinery\oil-heavy-NL	1.9647E-6	528.53E-9	Netherlands
processing\gas-I	1.5246E-6	4.5783E-6	Italy
compressor-GT-DK	1.4727E-6	567.67E-9	Denmark
coal-cogen-SE-D-Chem-el (proportional)	1.4051E-6	275.65E-6	Germany
gas-CC-cogen-big-D-Chem-el (proportional)	1.3816E-6	271.03E-6	Germany
waste-ST-A	1.3579E-6	4.0778E-6	Austria
compressor-GT-UK	1.1917E-6	3.5789E-6	United Kingdom
forestry\2-stroke-ICE-100% (end)	1.1892E-6	72.032E-6	Germany
gas-GT-ALG	1.1781E-6	3.5387E-6	Algeria
Xtra-onshore\gas-I	1.1434E-6	3.4337E-6	Italy
waste-ST-IRL	1.0026E-6	3.0113E-6	Ireland
oil-heavy-boiler-IRL	936.87E-9	2.8133E-6	Ireland
oil-heavy-boiler-A	898.04E-9	2.6968E-6	Austria
pipeline\gas-USA	895.08E-9	4.5751E-6	USA
truck-highway-east-<7.5 tons	890.68E-9	179.23E-6	local
compressor-GT-I	814.17E-9	2.4450E-6	Italy
forestry\debarker-100% (end)	807.17E-9	48.892E-6	Germany
Xtra-surface\coal-UK	691.41E-9	2.0761E-6	United Kingdom
wood-logs-boiler-D-wood-manufacturing	675.52E-9	40.917E-6	Germany
waste-ST-GR	642.78E-9	1.9303E-6	Greece
gas-boiler-DK	521.07E-9	386.85E-9	Denmark
oil-heavy-boiler-B	472.57E-9	1.4190E-6	Belgium
oil-heavy-boiler-SF	407.47E-9	1.2238E-6	Finland
compressor-GT-F	393.41E-9	1.1814E-6	France
refinery\oil-heavy-S	393.39E-9	78.317E-9	Sweden
diesel motor-UK	375.59E-9	1.1292E-6	United Kingdom
gas-boiler-UK	364.16E-9	1.0936E-6	United Kingdom
Xtra-onshore\gas-ALG	331.41E-9	995.31E-9	Algeria
processing\gas-ALG	331.41E-9	995.32E-9	Algeria
Xtra-offshore\gas-IRL	274.94E-9	825.79E-9	Ireland
xtra-onshore-secondary\oil-crude-I	245.14E-9	736.11E-9	Italy
gas-boiler-I	237.23E-9	712.41E-9	Italy
compressor-GT-E	213.33E-9	640.62E-9	Spain
processing\gas-IRL	171.84E-9	516.12E-9	Ireland
refinery\oil-heavy-I	137.40E-9	412.59E-9	Italy
xtra-onshore-secondary\oil-crude-GR	131.13E-9	393.76E-9	Greece
compressor-GT-IRL	90.744E-9	272.55E-9	Ireland
compressor-GT-A	86.695E-9	260.35E-9	Austria
refinery\oil-heavy-DK	84.191E-9	32.412E-9	Denmark
compressor-GT-SF	79.168E-9	237.78E-9	Finland
xtra-onshore-secondary\oil-crude-E	73.591E-9	220.99E-9	Spain
compressor-GT-ALG	72.206E-9	216.84E-9	Algeria
forestry\helicopter-100% (end)	56.996E-9	3.4524E-6	Germany
compressor-GT-P	46.460E-9	139.54E-9	Portugal
geothermal-ST-P	39.894E-9	119.82E-9	Portugal
refinery\oil-heavy-UK	38.750E-9	116.37E-9	United Kingdom

processing\gas-A	35.715E-9	107.25E-9	Austria
gas-boiler-IRL	27.729E-9	83.285E-9	Ireland
Xtra-onshore\gas-A	26.786E-9	80.439E-9	Austria
pipeline\gas-DK	26.752E-9	10.312E-9	Denmark
gas-boiler-ALG	23.347E-9	70.119E-9	Algeria
pipeline\gas-UK	21.648E-9	65.013E-9	United Kingdom
compressor-GT-GR	21.581E-9	64.809E-9	Greece
pipeline\gas-I	17.940E-9	53.874E-9	Italy
refinery\oil-heavy-E	16.499E-9	49.546E-9	Spain
refinery\oil-heavy-F	11.368E-9	34.137E-9	France
refinery\oil-heavy-GR	11.307E-9	33.954E-9	Greece
plastics\plastic-generic	9.1197E-9	2.1914E-9	generic
refinery\oil-heavy-P	8.3039E-9	24.940E-9	Portugal
pipeline\gas-F	7.1464E-9	21.461E-9	France
gas-boiler-A	5.5574E-9	16.689E-9	Austria
liquefaction\LNG-ALG	5.0601E-9	15.196E-9	Algeria
xtra-onshore-tertiary\oil-crude-F	4.9289E-9	14.801E-9	France
pipeline\gas-E	4.7005E-9	14.116E-9	Spain
refinery\oil-heavy-IRL	3.7196E-9	11.170E-9	Ireland
refinery\oil-heavy-A	3.6870E-9	11.072E-9	Austria
pipeline\gas-B	3.0101E-9	9.0394E-9	Belgium
pipeline\gas-NL->B	3.0101E-9	9.0388E-9	Netherlands
refinery\oil-heavy-B	1.9402E-9	5.8264E-9	Belgium
pipeline\gas-A	1.9103E-9	5.7366E-9	Austria
pipeline\gas-ALG	1.7485E-9	5.2509E-9	Algeria
refinery\oil-heavy-SF	1.6729E-9	5.0245E-9	Finland
pipeline\gas-IRL	1.6484E-9	4.9509E-9	Ireland
pipeline\gas-SF	1.4381E-9	4.3194E-9	Finland
pipeline\gas-P	1.0237E-9	3.0748E-9	Portugal
pipeline\gas-GR	392.0E-12	1.1773E-9	Greece
pipeline\gas-D-export	143.3E-12	430.3E-12	Germany
wood-chips-heat plant-D 1 MW'NSW	0.0000000	66.268344	Australia
Xtra-plantation\wood-short-rotation-D	0.0000000	106.09626	Germany
refinery\oil-heavy-USA	63.007E-9	1.3177E-6	USA
Xtra-onshore-tertiary\oil-crude-USA	363.37E-9	3.2750E-6	USA
refinery\oil-lite-USA	1.7449E-6	14.966E-6	USA
Xtra-surface\lignite-PL	2.5190E-6	232.01E-9	Poland
gas-boiler-USA	5.0212E-6	66.163E-6	USA
Xtra-offshore-primary\oil-crude-USA	28.334E-6	255.37E-6	USA
Xtra-offshore-secondary\oil-crude-USA	28.789E-6	259.47E-6	USA
oilgas-boiler-USA	157.53E-6	1.4198E-3	USA
oil-heavy-boiler-USA	440.61E-6	3.9689E-3	USA
coal-ST-RSA	6.7743E-3	21.758E-6	South Africa
lignite-ST-big-PL	8.1495E-3	750.62E-6	Poland
coal-ST-PL-retrofit	11.047E-3	1.0175E-3	Poland
Xtra-deep\coal-PL	12.871E-3	1.2091E-3	Poland
train-diesel-freight-USA	15.093E-3	1.2533E-3	USA
coal-ST-USA	21.502E-3	30.075E-3	USA
ship-freight-D-domestic	34.907E-3	21.330E-3	Germany
Xtra-deep\coal-RSA	77.020E-3	247.51E-6	South Africa
Xtra-mix\coal-USA	134.20E-3	11.163E-3	USA
Xtra-deep\coal-D	286.25E-3	2.1525056	Germany
coal-cogen-SE-D-Chem-th (proportional)	1.5420164	328.30E-3	Germany
gas-CC-cogen-big-D-Chem-th (proportional)	6.4206132	1.3669742	Germany
coal-cogen-BP-FGD-D-Chem-th (proportional)	25.669508	5.4651408	Germany

Appendix 3. Comparison of greenhouse gas emissions in option 3 and option 8[4]

Process	Greenhouse gas emissions (tonnes in CO_2 equivalents) Option 1	Option 6	Location
Sum	295.343E3	4.01966E3	
coal-boiler-AUS'NSW	278.575E3	0.0000000	Australia
Xtra-surface\coal-AUS	8.52340E3	778.99E-6	Australia
bagasse-ST-FJ-FSC'NSW	3.42173E3	3.42173E3	Fiji
coal-ST-AUS	1.94812E3	20.487E-3	Australia
train-diesel-freight-AUS	1.08485E3	4.2104E-3	Australia
diesel motor-AUS	723.79727	416.33E-6	Australia
chem-inorg\nitric acid	288.49162	61.073652	Germany
gas-GT-AUS	166.06129	1.7478E-3	Australia
oil-heavy-boiler-AUS	132.63344	372.23E-6	Australia
chem-inorg\ammonia	116.16988	24.642010	Germany
waste-ST-AUS	68.677390	722.22E-6	Australia
gas-boiler-D	55.882468	12.731220	Germany
blasting (ANFO)	27.596454	349.38E-6	generic
oil-heavy-ST-AUS	27.527554	289.48E-6	Australia
metal\pig-iron-D	20.759400	3.3264999	Germany
xtra-onshore-primary\oil-crude-OPEC	18.753214	2.1079498	OPEC
ship (ocean)	15.400666	1.7381579	generic
Xtra-offshore-secondary\oil-CAN	11.240771	174.92E-6	Canada
Xtra-offshore-primary\oil-crude-CAN	11.063419	172.16E-6	Canada
compressor-GT-GUS	10.158708	2.6428028	CIS
diesel motor-CAN	8.5782466	15.444E-3	Canada
lignite-ST-rhine	8.3808800	33.684146	Germany
nonmetallic minerals\cement clinker	7.7996958	481.33E-3	Germany
gas-ST-GUS	7.5170399	611.03E-3	CIS
hydro-dam-Tropics	7.4708633	47.872E-3	Tropics
metal\aluminium-CIS	7.3159700	10.017E-3	CIS
diesel motor-OPEC	7.2113231	804.28E-3	OPEC
oil-heavy-boiler-OPEC	7.2038073	585.40E-3	OPEC
coal-ST-CIS	7.1992395	585.20E-3	CIS
metal\aluminium-D	4.9826582	6.8222E-3	Germany
metal\aluminium-Tropics	4.1457163	5.6763E-3	Tropics
pipeline\gas-CIS	4.0711807	1.0591063	CIS
compressor-GT-AUS	3.1885729	55.997E-6	Australia
metal\aluminium-AUS	2.9263880	4.0068E-3	Australia
gas-CC-CAN	2.8000444	546.24E-6	Canada
gas-boiler-CAN	2.6905441	8.3140E-3	Canada
coal-ballast-ST-D	2.4179510	7.2536053	Germany
Xtra-onshore\gas-GUS	2.3656584	564.68E-3	CIS
oil-heavy-ST-CIS	2.3401344	190.22E-3	CIS
diesel motor-GUS	2.2348910	4.6885129	CIS
processing\sinter-D	2.1681425	347.43E-3	Germany
heat-process-cement-D-coal-100% (end)	2.0512762	126.49E-3	Germany
metal\aluminium-NOR	1.9509253	2.6712E-3	Norway
compressor-GT-NOR	1.7168715	450.73E-3	Norway
nonmetallic minerals\CaO-GGR-kiln	1.6981529	181.98E-3	Germany
processing\gas-AUS	1.4769431	25.938E-6	Australia
Xtra-onshore\gas-AUS	1.4760890	25.938E-6	Australia

In option 1, energy derived from coal and bagasse in the baseline scenario is 30% and 70% respectively while the proportion of energy derived from woodchips and bagasse is 30% and 70% respectively in option 6 under the mitigation scenario.

coal-boiler-GUS	1.4646356	2.0053E-3	CIS
heat-process-cement-D-l			
ignite-briquettes-rhine-100% (end)	1.3941508	85.967E-3	Germany
Xtra-onshore-secondary\oil-crude-OPEC	1.3599808	152.87E-3	OPEC
oil-heavy-boiler-Caribbean	1.3506787	1.8490E-3	Caribbean
oil-heavy-boiler-GUS	1.3118893	857.10E-3	CIS
gas-boiler-AUS	1.2772895	1.1778E-3	Australia
processing\gas-CIS	1.1352721	270.99E-3	CIS
Xtra-offshore-secondary\oil-crude-AUS	946.60E-3	3.9087E-6	Australia
gas-boiler-GUS	939.43E-3	130.64E-3	CIS
Xtra-offshore-primary\oil-crude-AUS	931.66E-3	3.8470E-6	Australia
Xtra-mix\coal-CIS	901.73E-3	59.498E-3	CIS
lignite-ST-D-Lausitz-retrofit	834.97E-3	7.6162786	Germany
Xtra-onshore\oil-crude-CIS	800.24E-3	1.8095215	CIS
compressor-GT-D	764.10E-3	198.78E-3	Germany
coal-ST-D	731.54E-3	31.848195	Germany
coal-boiler-AUS	697.60E-3	955.09E-6	Australia
waste-ST-D	697.50E-3	2.5130234	Germany
Xtra-offshore\gas-NOR	631.90E-3	165.89E-3	Norway
oil-heavy-boiler-CAN	628.61E-3	1.5828E-3	Canada
heat-process-cement-			
D-oil-heavy-100% (end)	577.84E-3	35.631E-3	Germany
oil-lite-boiler-D	516.82E-3	995.42E-6	Germany
refinery\oil-lite-AUS	501.72E-3	1.3520E-6	Australia
diesel motor generic	475.07E-3	109.52E-3	generic
heat-process-CaO-D-gas-100% (end)	463.35E-3	49.654E-3	Germany
propane-boiler-D	459.38E-3	1.3678753	Germany
coal-ST-CAN	426.20E-3	4.1820E-3	Canada
lignite-ST-D-Leipzig	417.38E-3	2.9657856	Germany
coal-boiler-Tropics	415.48E-3	568.84E-6	Tropics
gas-CC-D	409.03E-3	14.263E-3	Germany
processing\gas-NOR	394.95E-3	103.69E-3	Norway
compressor-GT-NL	379.04E-3	98.616E-3	Netherlands
diesel motor-Tropics	374.55E-3	512.76E-6	Tropics
nonmetallic minerals\CaO-kiln	299.69E-3	32.515E-3	Germany
gas-GT-GUS	289.69E-3	69.143E-3	CIS
oil-heavy-boiler-D	286.92E-3	854.34E-3	Germany
Xtra-deep\coal-D-Ballast	281.11E-3	843.35E-3	Germany
oil-lite-boiler-Tropics	280.43E-3	383.94E-6	Tropics
diesel motor-D	274.64E-3	94.853523	Germany
lignite-ST-D-Lausitz	269.78E-3	2.1158454	Germany
dieselmotor-powerplant-Caribbean	265.24E-3	363.10E-6	Caribbean
train-diesel-freight-BRA	258.96E-3	41.496E-3	Brazil
gas-GT-NOR	229.68E-3	152.88E-3	Norway
Xtra-onshore\gas-NL	228.94E-3	59.565E-3	Netherlands
processing\gas-NL	228.94E-3	59.565E-3	Netherlands
lignite-boiler-FBC-D-rhine	216.53E-3	13.352E-3	Germany
heat-process-CaO-D-coal-100% (end)	197.24E-3	21.399E-3	Germany
oi-lite-boiler-AUS	187.80E-3	257.11E-6	Australia
train-diesel-freight-CIS	172.94E-3	236.78E-6	CIS
diesel motor-Caribbean	166.54E-3	227.98E-6	Caribbean
processing\gas-D	155.30E-3	40.400E-3	Germany
Xtra-onshore\gas-D	155.30E-3	40.400E-3	Germany
oil-heavy-boiler-BRA	142.41E-3	22.821E-3	Brazil
oil-lite-boiler-NOR	127.86E-3	175.05E-6	Norway
compressor-GT-CAN	108.01E-3	173.92E-6	Canada
nonmetallic minerals\clay bricks	103.22E-3	16.544E-3	Germany
oilgas-boiler-D	97.152E-3	297.21E-3	Germany
pipeline\gas-AUS	96.602E-3	1.6954E-6	Australia
gas-boiler-S	85.735E-3	13.738E-3	Sweden

oil-heavy-boiler-big-generic	84.753E-3	19.612E-3	generic
gas-boiler-NOR	80.019E-3	62.186E-3	Norway
coal-boiler-FBC-D	71.407E-3	97.757E-6	Germany
gas-ST-D	69.640E-3	3.3564861	Germany
gas-CC-NL	66.807E-3	17.972E-3	Netherlands
coal-ST-NL	66.183E-3	17.804E-3	Netherlands
coal-boiler-Caribbean	64.876E-3	88.813E-6	Caribbean
Xtra-offshore-secondary\oil-EU	64.611E-3	194.06E-3	EU
Xtra-offshore-primary\oil-crude-EU	63.591E-3	191.00E-3	EU
waste-ST-CAN	61.932E-3	607.68E-6	Canada
metal\steel-D-EAF-new	51.395E-3	8.1585E-3	Germany
Xtra-onshore\gas-CAN	49.090E-3	78.994E-6	Canada
processing\gas-CAN	49.090E-3	79.048E-6	Canada
diesel motor-EU	48.768E-3	146.47E-3	EU
train-diesel-freight-Tropics	44.089E-3	60.359E-6	Tropics
refinery\oil-heavy-AUS	42.489E-3	175.35E-9	Australia
oil-heavy-ST-CAN	40.100E-3	393.47E-6	Canada
gas-CC-D-East	38.313E-3	1.7221521	Germany
train-diesel-freight-CAN	37.581E-3	6.0220E-3	Canada
coal-ST-big-generic	33.718E-3	13.965E-3	generic
gas-boiler-NL	31.579E-3	8.2160E-3	Netherlands
pipeline\gas-NOR	31.188E-3	8.1877E-3	Norway
oil-heavy-ST-D	29.205E-3	1.0754516	Germany
heat-process-coking-D-coke	27.525E-3	4.4096E-3	Germany
gas-GT-D	23.231E-3	911.94E-3	Germany
chem-inorg\sodium carbonate	19.447E-3	26.623E-6	Germany
pipeline\gas-D	16.838E-3	4.3799E-3	Germany
gas-CC-D-medium	16.375E-3	602.99E-3	Germany
coal-ST-D-coast	14.981E-3	722.06E-3	Germany
Xtra-surface\coal-CAN	14.701E-3	144.36E-6	Canada
diesel motor-USA	13.057E-3	82.402E-3	USA
truck+semi-trailer-highway-EURO 2	12.220E-3	2.4574378	local
truck+semi-trailer-highway-1980s	11.969E-3	2.4069506	local
Xtra-onshore-primary\crude-oil-generic	11.629E-3	2.6907E-3	generic
oil-heavy-ST-NL	10.765E-3	2.8960E-3	Netherlands
refinery\oil-lite-D	10.469E-3	32.986E-3	Germany
waste-ST-NL	10.350E-3	2.7841E-3	Netherlands
coal-ST-NOR	9.7769E-3	151.47E-6	Norway
truck+semi-trailer-highway-EURO 1	9.2817E-3	1.8664966	local
train-diesel-freight-Caribbean	9.0259E-3	12.356E-6	Caribbean
refinery\oil-heavy-OPEC	8.2231E-3	802.97E-6	OPEC
pipeline\Gas-NL	6.5864E-3	1.7136E-3	Netherlands
oil-heavy-ST-small-generic	6.4829E-3	1.5001E-3	generic
truck+trailer-highway-1980s-32-40 tons	5.6141E-3	1.1290682	local
coal-ST-RSA-Matimba	4.9321E-3	23.387E-3	South Africa
coal-ST-RSA-Duvha	4.7799E-3	22.665E-3	South Africa
coal-ST-RSA-Kendal	4.5768E-3	21.702E-3	South Africa
truck-city-1980s-<7.5 tons	3.9225E-3	789.30E-3	local
truck+semi-trailer-rural-1980s	3.8744E-3	779.12E-3	local
truck+semi-trailer-rural-EURO 2	3.5880E-3	721.52E-3	local
truck-rural-1980s-<7.5 tons	3.4620E-3	696.64E-3	local
truck+trailer-highway-1980s-<28 tons	3.2647E-3	656.46E-3	local
coal-ST-RSA-Matla	3.2124E-3	15.232E-3	South Africa
truck+trailer-highway-1980s-28-32 tons	3.2026E-3	643.99E-3	local
coal-ST-RSA-Tutuka	3.1822E-3	15.089E-3	South Africa
coal-ST-B	3.1761E-3	1.5398E-3	Belgium
truck+trailer-highway-EURO 1-32-40 tons	3.1695E-3	637.44E-3	local
coal-ST-RSA-Lethabo	3.0742E-3	14.577E-3	South Africa
refinery\oil-heavy-CIS	3.0234E-3	2.8634E-3	CIS
Xtra-surface\lignite-D-rhine	2.9444E-3	9.7146E-3	Germany

truck+semi-trailer-rural-EURO 1	2.7920E-3	561.45E-3	local
oil-distillate-GT-small-generic	2.7562E-3	637.76E-6	generic
coal-ST-RSA-Kriel	2.6343E-3	12.491E-3	South Africa
coal-ST-RSA-Hendrina	2.6191E-3	12.419E-3	South Africa
truck-highway-1980s-<7.5 tons	2.4455E-3	492.09E-3	local
waste-ST-S	2.4216E-3	482.11E-6	Sweden
refinery\oil-lite-CAN	2.4017E-3	5.9701E-6	Canada
truck+trailer-highway-EURO 2-32-40 tons	2.3915E-3	480.97E-3	local
Xtra-deep\coal-generic	2.2724E-3	941.24E-6	generic
coal-ST-S	2.2015E-3	438.29E-6	Sweden
truck+semi-trailer-city-1980s	2.1929E-3	440.93E-3	local
truck-city-1980s-14-20 tons	2.1319E-3	428.99E-3	local
truck+trailer-rural-1980s-32-40 tons	2.1157E-3	425.42E-3	local
oil-heavy-ST-S	2.0847E-3	415.04E-6	Sweden
truck-rural-1980s-20-28 tons	2.0311E-3	408.71E-3	local
pipeline\gas-CAN	1.9623E-3	3.1595E-6	Canada
truck-rural-1980s-14-20 tons	1.9444E-3	391.26E-3	local
Xtra-offshore\crude-oil-generic	1.9283E-3	446.19E-6	generic
truck+semi-trailer-city-EURO 2	1.9184E-3	385.73E-3	local
gas-GT-USA	1.8518E-3	9.3268E-3	USA
truck-highway-1980s-20-28 tons	1.8405E-3	370.35E-3	local
truck-city-1980s-20-28 tons	1.7497E-3	352.08E-3	local
Xtra-onshore-tertiary\oil-crude-D	1.6115E-3	4.9296E-3	Germany
truck-city-EURO 1-<7.5 tons	1.6000E-3	321.96E-3	local
truck+trailer-city-1980s-32-40 tons	1.5386E-3	309.37E-3	local
truck+semi-trailer-city-EURO 1	1.5163E-3	304.87E-3	local
truck+trailer-rural-1980s-<28 tons	1.4924E-3	300.10E-3	local
truck-highway-1980s-14-20 tons	1.4582E-3	293.42E-3	local
Xtra-onshore-secondory\crude-oil-generic	1.4536E-3	336.34E-6	generic
truck-rural-EURO 1-<7.5 tons	1.4132E-3	284.36E-3	local
truck+trailer-highway-EURO 1-28-32 tons	1.3707E-3	275.63E-3	local
truck-rural-EURO 1-20-28 tons	1.2893E-3	259.43E-3	local
truck+trailer-highway-EURO 1-<28 tons	1.2500E-3	251.34E-3	local
truck+trailer-rural-1980s-28-32 tons	1.1948E-3	240.26E-3	local
truck+trailer-rural-EURO 1-32-40 tons	1.1939E-3	240.07E-3	local
truck-highway-EURO 1-20-28 tons	1.1680E-3	235.02E-3	local
truck+trailer-city-1980s-<28 tons	1.1453E-3	230.30E-3	local
truck-city-EURO 1-20-28 tons	1.1107E-3	223.49E-3	local
truck-city-EURO 2-<7.5 tons	1.1004E-3	221.42E-3	local
truck-city-1980s-7.5-14 tons	1.0784E-3	216.99E-3	local
truck-rural-1980s-7.5-14 tons	1.0010E-3	201.43E-3	local
truck-highway-EURO 1-<7.5 tons	997.96E-6	200.81E-3	local
truck-rural-EURO 2-20-28 tons	996.31E-6	200.48E-3	local
truck+trailer-city-1980s-28-32 tons	996.19E-6	200.31E-3	local
truck-rural-EURO 2-14-20 tons	974.33E-6	196.06E-3	local
truck-rural-EURO 2-<7.5 tons	972.17E-6	195.62E-3	local
wood-ST-small-D	939.47E-6	45.280E-3	Germany
truck+trailer-highway-EURO 2-28-32 tons	919.73E-6	184.94E-3	local
truck-highway-EURO 2-20-28 tons	902.58E-6	181.62E-3	local
truck+trailer-rural-EURO 2-32-40 tons	900.83E-6	181.14E-3	local
truck-city-EURO 1-14-20 tons	897.60E-6	180.62E-3	local
coal-ST-RSA-Arnot	873.23E-6	4.1406E-3	South Africa
truck+trailer-highway-EURO 2-<32 tons	871.98E-6	175.34E-3	local
truck+trailer-city-EURO 1-32-40 tons	868.00E-6	174.54E-3	local
truck-city-EURO 2-20-28 tons	858.20E-6	172.69E-3	local
truck-highway-1980s-7.5-14 tons	822.38E-6	165.48E-3	local
truck-rural-EURO 1-14-20 tons	819.50E-6	164.90E-3	local
oil-naphtha-boiler-D	752.40E-6	147.61E-3	Germany
oil-heavy-boiler-NL	743.80E-6	200.10E-6	Netherlands
oil-heavy-ST-I	728.57E-6	2.1879E-3	Italy

truck-highway-EURO 2-<7.5 tons	686.56E-6	138.15E-3	local
gas-GT-S	674.98E-6	134.38E-6	Sweden
waste-ST-USA	658.65E-6	3.2145E-3	USA
truck+trailer-city-EURO 2-32-40 tons	654.89E-6	131.68E-3	local
coal-ST-UK	654.58E-6	1.9662E-3	United Kingdom
truck-city-EURO 2-14-20 tons	626.80E-6	126.13E-3	local
truck-highway-EURO 1-14-20 tons	614.35E-6	123.62E-3	local
coal-ST-E	588.08E-6	1.7660E-3	Spain
truck+trailer-rural-EURO 1-<28 tons	576.19E-6	115.86E-3	local
gas-CC-DK	575.43E-6	221.53E-6	Denmark
refinery\oil-heavy-D	540.21E-6	701.09E-6	Germany
train-dieselmotor-generic	514.29E-6	149.50E-6	generic
truck+trailer-rural-EURO 1-28-32 tons	511.37E-6	102.83E-3	local
truck+trailer-highway-1970s-<28 tons	489.58E-6	98.444E-3	local
truck-city-1970s-<7.5 tons	480.92E-6	96.773E-3	local
gas-CC-UK	465.73E-6	1.3989E-3	United Kingdom
oil-heavy-ST-DK	446.17E-6	171.77E-6	Denmark
truck+trailer-highway-1970s-32-40 tons	444.69E-6	89.433E-3	local
truck+trailer-city-EURO 1-<28 tons	442.41E-6	88.960E-3	local
truck+trailer-city-EURO 1-28-32 tons	426.35E-6	85.731E-3	local
truck-rural-1970s-<7.5 tons	424.35E-6	85.388E-3	local
truck+trailer-highway-1970s-28-32 tons	405.78E-6	81.593E-3	local
truck+trailer-rural-EURO 2-<28 tons	400.99E-6	80.630E-3	local
truck-city-EURO 1-7.5-14 tons	391.46E-6	78.771E-3	local
coal-ST-UK-with-FGD	384.93E-6	1.1562E-3	United Kingdom
Xtra-surface\coal-generic	365.03E-6	151.20E-6	generic
truck-rural-EURO 1-7.5-14 tons	363.52E-6	73.149E-3	local
truck+trailer-rural-EURO 2-28-32 tons	343.11E-6	68.993E-3	local
Xtra-surface\lignite-D-Lausitz	341.79E-6	3.0096E-3	Germany
lignite-ST-GR	329.87E-6	990.62E-6	Greece
truck+trailer-city-EURO 2-<28 tons	307.69E-6	61.871E-3	local
oil-heavy-ST-USA	306.19E-6	1.4944E-3	USA
gas-CC-I	303.44E-6	911.25E-6	Italy
truck-highway-1970s-<7.5 tons	299.81E-6	60.328E-3	local
truck-highway-EURO 1-7.5-14 tons	298.67E-6	60.099E-3	local
truck+trailer-city-EURO 2-28-32 tons	286.05E-6	57.519E-3	local
truck+semi-trailer-highway-1970s	283.45E-6	56.999E-3	local
truck-city-EURO 2-7.5-14 tons	276.66E-6	55.670E-3	local
coal-ST-F-Import	271.56E-6	815.50E-6	France
truck-city-1970s-14-20 tons	270.25E-6	54.381E-3	local
truck-rural-EURO 2-7.5-14 tons	256.96E-6	51.707E-3	local
Refinery\diesel-generic	248.76E-6	57.362E-6	generic
coal-ST-I	247.02E-6	741.81E-6	Italy
truck-rural-1970s-14-20 tons	246.31E-6	49.563E-3	local
waste-ST-DK	236.33E-6	90.983E-6	Denmark
truck+trailer-rural-1970s-<28 tons	218.50E-6	43.936E-3	local
truck-highway-EURO 2-7.5-14 tons	211.11E-6	42.481E-3	local
oil-heavy-ST-UK	204.90E-6	615.46E-6	United Kingdom
truck-city-1970s-7.5-14 tons	192.74E-6	38.783E-3	local
coal-ST-SF	187.54E-6	563.27E-6	Finland
truck-highway-1970s-14-20 tons	184.73E-6	37.172E-3	local
truck-rural-1970s-7.5-14 tons	178.85E-6	35.989E-3	local
refinery\oil-heavy-CAN	177.47E-6	524.22E-9	Canada
truck+trailer-rural-1970s-32-40 tons	167.52E-6	33.685E-3	local
truck+trailer-city-1970s-<28 tons	167.32E-6	33.645E-3	local
refinery\liquid gas	151.42E-6	451.33E-6	Germany
truck+trailer-rural-1970s-28-32 tons	151.40E-6	30.444E-3	local
truck-highway-1970s-7.5-14 tons	146.97E-6	29.575E-3	local
oil-heavy-boiler-S	143.73E-6	28.614E-6	Sweden
Xtra-surface\lignite-D-Leipzig	126.60E-6	899.65E-6	Germany

truck+trailer-city-1970s-28-32 tons	126.27E-6	25.391E-3	local
truck+semi-trailer-rural-1970s	125.88E-6	25.313E-3	local
truck+trailer-city-1970s-32-40 tons	121.86E-6	24.503E-3	local
coal-ST-P	119.96E-6	360.29E-6	Portugal
truck-rural-1970s-20-28 tons	113.35E-6	22.809E-3	local
truck-highway-1970s-20-28 tons	102.69E-6	20.664E-3	local
geothermal-ST-CAN	99.517E-6	976.47E-9	Canada
truck-city-1970s-20-28 tons	97.724E-6	19.664E-3	local
oil-heavy-ST-E	87.480E-6	262.70E-6	Spain
coal-ST-IRL	82.463E-6	247.68E-6	Ireland
metal\copper-D-primary	81.949E-6	1.6363E-3	Germany
truck+semi-trailer-city-1970s	81.691E-6	16.426E-3	local
gas-CC-E	79.600E-6	239.04E-6	Spain
Xtra-deep\coal-E	78.050E-6	234.38E-6	Spain
waste-ST-SF	74.069E-6	222.47E-6	Finland
coal-ST-A	70.400E-6	211.41E-6	Austria
Xtra-deep\coal-UK	68.982E-6	207.13E-6	United Kingdom
Xtra-onshore-tertiary\oilgas	67.067E-6	207.14E-6	Germany
gas-GT-F	61.901E-6	185.89E-6	France
compressor-GT-USA	60.933E-6	311.45E-6	USA
oil-heavy-ST-GR	59.937E-6	179.99E-6	Greece
oil-heavy-ST-F	59.700E-6	179.28E-6	France
gas-CC-B	54.885E-6	164.82E-6	Belgium
oil-heavy-boiler-I	50.240E-6	150.86E-6	Italy
Refinery\oil-products-generic	46.949E-6	10.864E-6	generic
waste-ST-UK	44.555E-6	133.83E-6	United Kingdom
oil-heavy-ST-P	44.036E-6	132.26E-6	Portugal
waste-ST-I	43.708E-6	131.26E-6	Italy
truck-rural-East-7.5-14 tons	37.125E-6	7.4704E-3	local
truck+trailer-rural-East-<28 tons	36.995E-6	7.4390E-3	local
refinery\oil-lite-NOR	35.788E-6	48.997E-9	Norway
gas-CC-IRL	35.463E-6	106.52E-6	Ireland
conversion\coke-D	33.476E-6	5.3629E-6	Germany
gas-CC-A	32.341E-6	97.121E-6	Austria
gas-CC-SF	30.976E-6	93.038E-6	Finland
oil-heavy-boiler-DK	30.760E-6	11.842E-6	Denmark
Truck-very-big-diesel-rural-generic	22.538E-6	5.4162E-6	generic
oil-heavy-ST-IRL	20.398E-6	61.265E-6	Ireland
oil-heavy-ST-A	19.539E-6	58.676E-6	Austria
waste-ST-F	18.425E-6	55.332E-6	France
truck+trailer-city-East-<28 tons	18.154E-6	3.6504E-3	local
gas-CC-P	17.336E-6	52.069E-6	Portugal
Xtra-onshore\gas-USA	17.134E-6	87.420E-6	USA
processing\gas-USA	17.116E-6	87.487E-6	USA
waste-ST-E	16.901E-6	50.754E-6	Spain
truck-city-East-7.5-14 tons	16.697E-6	3.3599E-3	local
oil-heavy-boiler-UK	14.158E-6	42.517E-6	United Kingdom
refinery\oil-products-EU	13.593E-6	40.823E-6	EU
xtra-onshore-secondary\oil-crude-NL	13.144E-6	3.5361E-6	Netherlands
forestry\dieselmotor-100% (end)	10.727E-6	649.74E-6	Germany
waste-ST-P	10.349E-6	31.083E-6	Portugal
oil-heavy-ST-B	10.289E-6	30.898E-6	Belgium
Xtra-surface\lignite-GR	10.240E-6	30.750E-6	Greece
geothermal-ST-USA	9.4562E-6	46.151E-6	USA
truck-rural-East-<7.5 tons	8.9140E-6	1.7937E-3	local
oil-heavy-ST-SF	8.8713E-6	26.645E-6	Finland
gas-CC-GR	8.4441E-6	25.358E-6	Greece
waste-ST-B	8.3396E-6	25.044E-6	Belgium
Xtra-offshore\gas-DK	7.7499E-6	5.7536E-6	Denmark

coal-cogen-BP-FGD-D-Chem-el (proportional)	6.5602E-6	1.2870E-3	Germany
oil-heavy-boiler-E	6.0405E-6	18.139E-6	Spain
truck+trailer-highway-East-<28 tons	5.9498E-6	1.1964E-3	local
Xtra-offshore\gas-UK	5.4161E-6	16.266E-6	United Kingdom
truck-highway-East-7.5-14 tons	5.3792E-6	1.0824E-3	local
processing\gas-DK	4.8437E-6	3.5960E-6	Denmark
oil-heavy-boiler-F	4.7338E-6	14.216E-6	France
geothermal-ST-I	4.6732E-6	14.034E-6	Italy
oil-heavy-boiler-GR	4.1536E-6	12.473E-6	Greece
truck-city-East-<7.5 tons	3.9349E-6	791.80E-6	local
processing\gas-UK	3.3851E-6	10.166E-6	United Kingdom
oil-heavy-boiler-P	3.0339E-6	9.1120E-6	Portugal
forestry-raising\spruce-abs.dry	2.9539E-6	178.93E-6	Germany
refinery\oil-heavy-NL	2.9471E-6	792.79E-9	Netherlands
processing\gas-I	2.2869E-6	6.8675E-6	Italy
compressor-GT-DK	2.2090E-6	851.51E-9	Denmark
coal-cogen-SE-D-Chem-el (proportional)	2.1076E-6	413.47E-6	Germany
gas-CC-cogen-big-D-Chem-el (proportional)	2.0723E-6	406.55E-6	Germany
waste-ST-A	2.0369E-6	6.1168E-6	Austria
compressor-GT-UK	1.7876E-6	5.3684E-6	United Kingdom
forestry\2-stroke-ICE-100% (end)	1.7838E-6	108.05E-6	Germany
gas-GT-ALG	1.7671E-6	5.3080E-6	Algeria
Xtra-onshore\gas-I	1.7151E-6	5.1506E-6	Italy
waste-ST-IRL	1.5039E-6	4.5169E-6	Ireland
oil-heavy-boiler-IRL	1.4053E-6	4.2200E-6	Ireland
oil-heavy-boiler-A	1.3471E-6	4.0452E-6	Austria
pipeline\gas-USA	1.3426E-6	6.8626E-6	USA
truck-highway-east-<7.5 tons	1.3360E-6	268.84E-6	local
compressor-GT-I	1.2213E-6	3.6675E-6	Italy
forestry\debarker-100% (end)	1.2108E-6	73.338E-6	Germany
Xtra-surface\coal-UK	1.0371E-6	3.1141E-6	United Kingdom
wood-logs-boiler-D-wood-manufacturing	1.0133E-6	61.376E-6	Germany
waste-ST-GR	964.16E-9	2.8954E-6	Greece
gas-boiler-DK	781.61E-9	580.28E-9	Denmark
oil-heavy-boiler-B	708.86E-9	2.1285E-6	Belgium
oil-heavy-boiler-SF	611.20E-9	1.8357E-6	Finland
compressor-GT-F	590.11E-9	1.7721E-6	France
refinery\oil-heavy-S	590.08E-9	117.48E-9	Sweden
diesel motor-UK	563.38E-9	1.6937E-6	United Kingdom
gas-boiler-UK	546.24E-9	1.6405E-6	United Kingdom
processing\gas-ALG	497.11E-9	1.4930E-6	Algeria
Xtra-onshore\gas-ALG	497.11E-9	1.4930E-6	Algeria
Xtra-offshore\gas-IRL	412.42E-9	1.2387E-6	Ireland
xtra-onshore-secondary\oil-crude-I	367.70E-9	1.1042E-6	Italy
gas-boiler-I	355.85E-9	1.0686E-6	Italy
compressor-GT-E	319.99E-9	960.94E-9	Spain
processing\gas-IRL	257.76E-9	774.18E-9	Ireland
refinery\oil-heavy-I	206.09E-9	618.89E-9	Italy
xtra-onshore-secondary\oil-crude-GR	196.69E-9	590.64E-9	Greece
compressor-GT-IRL	136.12E-9	408.82E-9	Ireland
compressor-GT-A	130.04E-9	390.52E-9	Austria
refinery\oil-heavy-DK	126.29E-9	48.619E-9	Denmark
compressor-GT-SF	118.75E-9	356.68E-9	Finland
xtra-onshore-secondary\oil-crude-E	110.39E-9	331.48E-9	Spain
compressor-GT-ALG	108.31E-9	325.25E-9	Algeria
forestry\helicopter-100% (end)	85.494E-9	5.1785E-6	Germany
compressor-GT-P	69.689E-9	209.31E-9	Portugal
geothermal-ST-P	59.841E-9	179.74E-9	Portugal
refinery\oil-heavy-UK	58.126E-9	174.56E-9	United Kingdom

processing\gas-A	53.572E-9	160.88E-9	Austria
gas-boiler-IRL	41.594E-9	124.93E-9	Ireland
Xtra-onshore\gas-A	40.179E-9	120.66E-9	Austria
pipeline\gas-DK	40.127E-9	15.468E-9	Denmark
gas-boiler-ALG	35.021E-9	105.18E-9	Algeria
pipeline\gas-UK	32.472E-9	97.519E-9	United Kingdom
compressor-GT-GR	32.372E-9	97.214E-9	Greece
pipeline\gas-I	26.910E-9	80.811E-9	Italy
refinery\oil-heavy-E	24.748E-9	74.319E-9	Spain
refinery\oil-heavy-F	17.052E-9	51.206E-9	France
refinery\oil-heavy-GR	16.960E-9	50.931E-9	Greece
plastics\plastic-generic	13.680E-9	3.2871E-9	generic
refinery\oil-heavy-P	12.456E-9	37.410E-9	Portugal
pipeline\gas-F	10.720E-9	32.191E-9	France
gas-boiler-A	8.3361E-9	25.034E-9	Austria
liquefaction\LNG-ALG	7.5901E-9	22.793E-9	Algeria
xtra-onshore-tertiary\oil-crude-F	7.3934E-9	22.201E-9	France
pipeline\gas-E	7.0508E-9	21.174E-9	Spain
refinery\oil-heavy-IRL	5.5794E-9	16.755E-9	Ireland
refinery\oil-heavy-A	5.5305E-9	16.608E-9	Austria
pipeline\gas-B	4.5151E-9	13.559E-9	Belgium
pipeline\gas-NL->B	4.5151E-9	13.558E-9	Netherlands
refinery\oil-heavy-B	2.9103E-9	8.7396E-9	Belgium
pipeline\gas-A	2.8654E-9	8.6050E-9	Austria
pipeline\gas-ALG	2.6228E-9	7.8764E-9	Algeria
refinery\oil-heavy-SF	2.5093E-9	7.5367E-9	Finland
pipeline\gas-IRL	2.4726E-9	7.4264E-9	Ireland
pipeline\gas-SF	2.1572E-9	6.4791E-9	Finland
pipeline\gas-P	1.5356E-9	4.6122E-9	Portugal
pipeline\gas-GR	588.0E-12	1.7659E-9	Greece
pipeline\gas-D-export	214.9E-12	645.4E-12	Germany
wood-chips-heat plant-D 1 MW'NSW	0.0000000	99.402517	Australia
Xtra-plantation\wood-short-rotation-D	0.0000000	159.14439	Germany
refinery\oil-heavy-USA	94.510E-9	1.9765E-6	USA
Xtra-onshore-tertiary\oil-crude-USA	545.06E-9	4.9125E-6	USA
refinery\oil-lite-USA	2.6173E-6	22.449E-6	USA
Xtra-surface\lignite-PL	3.7785E-6	348.02E-9	Poland
gas-boiler-USA	7.5318E-6	99.244E-6	USA
Xtra-offshore-primary\oil-crude-USA	42.502E-6	383.06E-6	USA
Xtra-offshore-secondary\oil-crude-USA	43.183E-6	389.20E-6	USA
oilgas-boiler-USA	236.29E-6	2.1297E-3	USA
oil-heavy-boiler-USA	660.92E-6	5.9533E-3	USA
coal-ST-RSA	10.161E-3	32.637E-6	South Africa
lignite-ST-big-PL	12.224E-3	1.1259E-3	Poland
coal-ST-PL-retrofit	16.571E-3	1.5263E-3	Poland
Xtra-deep\coal-PL	19.307E-3	1.8136E-3	Poland
train-diesel-freight-USA	22.640E-3	1.8799E-3	USA
coal-ST-USA	32.254E-3	45.112E-3	USA
ship-freight-D-domestic	52.361E-3	31.995E-3	Germany
Xtra-deep\coal-RSA	115.53E-3	371.27E-6	South Africa
Xtra-mix\coal-USA	201.30E-3	16.745E-3	USA
Xtra-deep\coal-D	429.38E-3	3.2287584	Germany
coal-cogen-SE-D-Chem-th (proportional)	2.3130246	492.45E-3	Germany
gas-CC-cogen-big-D-Chem-th (proportional)-	9.6309199	2.0504613	Germany
coal-cogen-BP-FGD-D-Chem-th (proportional)	38.504262	8.1977113	Germany

Appendix 4. Comparison of greenhouse gas emissions in option 4 and option 9[5]

Process	Greenhouse gas emissions (tonnes in CO_2 equivalents) Option 1	Option 6	Location
Sum	392.161E3	3.73016E3	
coal-boiler-AUS'NSW	371.433E3	0.0000000	Australia
Xtra-surface\coal-AUS	11.3645E3	1.0386E-3	Australia
bagasse-ST-FJ-FSC'NSW	2.93291E3	2.93291E3	Fiji
coal-ST-AUS	2.59750E3	27.316E-3	Australia
train-diesel-freight-AUS	1.44647E3	5.6139E-3	Australia
diesel motor-AUS	965.06302	555.11E-6	Australia
chem-inorg\nitric acid	384.65549	81.431537	Germany
gas-GT-AUS	221.41505	2.3304E-3	Australia
oil-heavy-boiler-AUS	176.84459	496.31E-6	Australia
chem-inorg\ammonia	154.89317	32.856014	Germany
waste-ST-AUS	91.569854	962.96E-6	Australia
gas-boiler-D	74.509957	16.974960	Germany
blasting (ANFO)	36.795272	465.85E-6	generic
oil-heavy-ST-AUS	36.703406	385.98E-6	Australia
metal\pig-iron-D	27.679199	4.4353332	Germany
xtra-onshore-primary\oil-crude-OPEC	25.004286	2.8105998	OPEC
ship (ocean)	20.534222	2.3175438	generic
Xtra-offshore-secondary\oil-CAN	14.987695	233.23E-6	Canada
Xtra-offshore-primary\oil-crude-CAN	14.751225	229.55E-6	Canada
compressor-GT-GUS	13.544944	3.5237371	CIS
diesel motor-CAN	11.437662	20.592E-3	Canada
lignite-ST-rhine	11.174507	44.912194	Germany
nonmetallic minerals\cement clinker	10.399594	641.77E-3	Germany
gas-ST-GUS	10.022720	814.71E-3	CIS
hydro-dam-Tropics	9.9611510	63.830E-3	Tropics
metal\aluminium-CIS	9.7546267	13.356E-3	CIS
diesel motor-OPEC	9.6150975	1.0723751	OPEC
oil-heavy-boiler-OPEC	9.6050764	780.54E-3	OPEC
coal-ST-CIS	9.5989860	780.27E-3	CIS
metal\aluminium-D	6.6435443	9.0963E-3	Germany
metal\aluminium-Tropics	5.5276218	7.5683E-3	Tropics
pipeline\gas-CIS	5.4282410	1.4121418	CIS
compressor-GT-AUS	4.2514305	74.662E-6	Australia
metal\aluminium-AUS	3.9018507	5.3424E-3	Australia
gas-CC-CAN	3.7333926	728.33E-6	Canada
gas-boiler-CAN	3.5873921	11.085E-3	Canada
coal-ballast-ST-D	3.2239346	9.6714737	Germany
Xtra-onshore\gas-GUS	3.1542112	752.91E-3	CIS
oil-heavy-ST-CIS	3.1201792	253.63E-3	CIS
diesel motor-GUS	2.9798547	6.2513506	CIS
processing\sinter-D	2.8908567	463.23E-3	Germany
heat-process-cement-D-coal-100% (end)	2.7350350	168.65E-3	Germany
metal\aluminium-NOR	2.6012338	3.5616E-3	Norway
compressor-GT-NOR	2.2891619	600.98E-3	Norway
nonmetallic minerals\CaO-GGR-kiln	2.2642039	242.64E-3	Germany
processing\gas-AUS	1.9692575	34.584E-6	Australia

[5] In option 1, energy derived from coal and bagasse in the baseline scenario is 40% and 60% respectively while the proportion of energy derived from woodchips and bagasse is 40% and 60% respectively in option 6 under the mitigation scenario.

Xtra-onshore\gas-AUS	1.9681187	34.584E-6	Australia
coal-boiler-GUS	1.9528474	2.6737E-3	CIS
heat-process-cement-D-lignite-briquettes-rhine-100% (end)	1.8588678	114.62E-3	Germany
Xtra-onshore-secondary\oil-crude-OPEC	1.8133077	203.82E-3	OPEC
oil-heavy-boiler-Caribbean	1.8009050	2.4654E-3	Caribbean
oil-heavy-boiler-GUS	1.7491858	1.1427983	CIS
gas-boiler-AUS	1.7030527	1.5704E-3	Australia
processing\gas-CIS	1.5136962	361.32E-3	CIS
Xtra-offshore-secondary\oil-crude-AUS	1.2621282	5.2116E-6	Australia
gas-boiler-GUS	1.2525777	174.19E-3	CIS
Xtra-offshore-primary\oil-crude-AUS	1.2422148	5.1294E-6	Australia
Xtra-mix\coal-CIS	1.2023028	79.330E-3	CIS
lignite-ST-D-Lausitz-retrofit	1.1132988	10.155038	Germany
Xtra-onshore\oil-crude-CIS	1.0669808	2.4126953	CIS
compressor-GT-D	1.0187995	265.03E-3	Germany
coal-ST-D	975.38E-3	42.464260	Germany
coal-boiler-AUS	930.13E-3	1.2735E-3	Australia
waste-ST-D	930.00E-3	3.3506979	Germany
Xtra-offshore\gas-NOR	842.54E-3	221.19E-3	Norway
oil-heavy-boiler-CAN	838.14E-3	2.1104E-3	Canada
heat-process-cement-D-oil-heavy-100% (end)	770.45E-3	47.508E-3	Germany
oil-lite-boiler-D	689.09E-3	1.3272E-3	Germany
refinery\oil-lite-AUS	668.97E-3	1.8027E-6	Australia
diesel motor generic	633.43E-3	146.02E-3	generic
heat-process-CaO-D-gas-100% (end)	617.80E-3	66.205E-3	Germany
propane-boiler-D	612.51E-3	1.8238338	Germany
coal-ST-CAN	568.27E-3	5.5760E-3	Canada
lignite-ST-D-Leipzig	556.51E-3	3.9543808	Germany
coal-boiler-Tropics	553.97E-3	758.45E-6	Tropics
gas-CC-D	545.38E-3	19.017E-3	Germany
processing\gas-NOR	526.59E-3	138.25E-3	Norway
compressor-GT-NL	505.38E-3	131.49E-3	Netherlands
diesel motor-Tropics	499.40E-3	683.67E-6	Tropics
nonmetallic minerals\CaO-kiln	399.59E-3	43.354E-3	Germany
gas-GT-GUS	386.25E-3	92.191E-3	CIS
oil-heavy-boiler-D	382.56E-3	1.1391261	Germany
Xtra-deep\coal-D-Ballast	374.81E-3	1.1244624	Germany
oil-lite-boiler-Tropics	373.91E-3	511.92E-6	Tropics
diesel motor-D	366.18E-3	126.47136	Germany
lignite-ST-D-Lausitz	359.71E-3	2.8211272	Germany
dieselmotor-powerplant-Caribbean	353.65E-3	484.13E-6	Caribbean
train-diesel-freight-BRA	345.28E-3	55.328E-3	Brazil
gas-GT-NOR	306.24E-3	203.85E-3	Norway
Xtra-onshore\gas-NL	305.25E-3	79.420E-3	Netherlands
processing\gas-NL	305.25E-3	79.420E-3	Netherlands
lignite-boiler-FBC-D-rhine	288.71E-3	17.803E-3	Germany
heat-process-CaO-D-coal-100% (end)	262.98E-3	28.532E-3	Germany
oi-lite-boiler-AUS	250.40E-3	342.82E-6	Australia
train-diesel-freight-CIS	230.59E-3	315.70E-6	CIS
diesel motor-Caribbean	222.05E-3	303.97E-6	Caribbean
processing\gas-D	207.06E-3	53.867E-3	Germany
Xtra-onshore\gas-D	207.06E-3	53.867E-3	Germany
oil-heavy-boiler-BRA	189.89E-3	30.428E-3	Brazil
oil-lite-boiler-NOR	170.48E-3	233.41E-6	Norway
compressor-GT-CAN	144.01E-3	231.89E-6	Canada
nonmetallic minerals\clay bricks	137.62E-3	22.058E-3	Germany
oilgas-boiler-D	129.54E-3	396.27E-3	Germany
pipeline\gas-AUS	128.80E-3	2.2605E-6	Australia

gas-boiler-S	114.31E-3	18.318E-3	Sweden
oil-heavy-boiler-big-generic	113.00E-3	26.150E-3	generic
gas-boiler-NOR	106.69E-3	82.915E-3	Norway
coal-boiler-FBC-D	95.210E-3	130.34E-6	Germany
gas-ST-D	92.853E-3	4.4753148	Germany
gas-CC-NL	89.076E-3	23.962E-3	Netherlands
coal-ST-NL	88.244E-3	23.739E-3	Netherlands
coal-boiler-Caribbean	86.502E-3	118.42E-6	Caribbean
Xtra-offshore-secondary\oil-EU	86.148E-3	258.74E-3	EU
Xtra-offshore-primary\oil-crude-EU	84.788E-3	254.66E-3	EU
waste-ST-CAN	82.576E-3	810.25E-6	Canada
metal\steel-D-EAF-new	68.527E-3	10.878E-3	Germany
Xtra-onshore\gas-CAN	65.454E-3	105.33E-6	Canada
processing\gas-CAN	65.454E-3	105.40E-6	Canada
diesel motor-EU	65.025E-3	195.29E-3	EU
train-diesel-freight-Tropics	58.785E-3	80.479E-6	Tropics
refinery\oil-heavy-AUS	56.652E-3	233.80E-9	Australia
oil-heavy-ST-CAN	53.466E-3	524.62E-6	Canada
gas-CC-D-East	51.084E-3	2.2962028	Germany
train-diesel-freight-CAN	50.108E-3	8.0293E-3	Canada
coal-ST-big-generic	44.957E-3	18.620E-3	generic
gas-boiler-NL	42.105E-3	10.955E-3	Netherlands
pipeline\gas-NOR	41.583E-3	10.917E-3	Norway
oil-heavy-ST-D	38.940E-3	1.4339354	Germany
heat-process-coking-D-coke	36.700E-3	5.8794E-3	Germany
gas-GT-D	30.974E-3	1.2159139	Germany
chem-inorg\sodium carbonate	25.929E-3	35.498E-6	Germany
pipeline\gas-D	22.450E-3	5.8399E-3	Germany
gas-CC-D-medium	21.833E-3	803.98E-3	Germany
coal-ST-D-coast	19.975E-3	962.75E-3	Germany
Xtra-surface\coal-CAN	19.601E-3	192.48E-6	Canada
diesel motor-USA	17.409E-3	109.87E-3	USA
truck+semi-trailer-highway-EURO 2	16.294E-3	3.2765837	local
truck+semi-trailer-highway-1980s	15.959E-3	3.2092675	local
Xtra-onshore-primary\crude-oil-generic	15.505E-3	3.5877E-3	generic
oil-heavy-ST-NL	14.354E-3	3.8613E-3	Netherlands
efinery\oil-lite-D	13.959E-3	43.981E-3	Germany
waste-ST-NL	13.799E-3	3.7122E-3	Netherlands
coal-ST-NOR	13.036E-3	201.96E-6	Norway
truck+semi-trailer-highway-EURO 1	12.376E-3	2.4886621	local
train-diesel-freight-Caribbean	12.034E-3	16.475E-6	Caribbean
refinery\oil-heavy-OPEC	10.964E-3	1.0706E-3	OPEC
pipeline\Gas-NL	8.7818E-3	2.2847E-3	Netherlands
oil-heavy-ST-small-generic	8.6439E-3	2.0001E-3	generic
truck+trailer-highway-1980s-32-40 tons	7.4855E-3	1.5054243	local
coal-ST-RSA-Matimba	6.5761E-3	31.182E-3	South Africa
coal-ST-RSA-Duvha	6.3733E-3	30.220E-3	South Africa
coal-ST-RSA-Kendal	6.1024E-3	28.936E-3	South Africa
truck-city-1980s-<7.5 tons	5.2300E-3	1.0524017	local
truck+semi-trailer-rural-1980s	5.1659E-3	1.0388324	local
truck+semi-trailer-rural-EURO 2	4.7840E-3	962.02E-3	local
truck-rural-1980s-<7.5 tons	4.6161E-3	928.85E-3	local
truck+trailer-highway-1980s-<28 tons	4.3529E-3	875.28E-3	local
coal-ST-RSA-Matla	4.2831E-3	20.309E-3	South Africa
truck+trailer-highway-1980s-28-32 tons	4.2702E-3	858.65E-3	local
coal-ST-RSA-Tutuka	4.2429E-3	20.118E-3	South Africa
coal-ST-B	4.2347E-3	2.0530E-3	Belgium
truck+trailer-highway-EURO 1-32-40 tons	4.2260E-3	849.91E-3	local
coal-ST-RSA-Lethabo	4.0990E-3	19.436E-3	South Africa
refinery\oil-heavy-CIS	4.0311E-3	3.8178E-3	CIS

Xtra-surface\lignite-D-rhine	3.9258E-3	12.953E-3	Germany
truck+semi-trailer-rural-EURO 1	3.7226E-3	748.60E-3	local
oil-distillate-GT-small-generic	3.6750E-3	850.35E-6	generic
coal-ST-RSA-Kriel	3.5124E-3	16.655E-3	South Africa
coal-ST-RSA-Hendrina	3.4922E-3	16.559E-3	South Africa
truck-highway-1980s-<7.5 tons	3.2607E-3	656.12E-3	local
waste-ST-S	3.2288E-3	642.82E-6	Sweden
refinery\oil-lite-CAN	3.2023E-3	7.9601E-6	Canada
truck+trailer-highway-EURO 2-32-40 tons	3.1887E-3	641.29E-3	local
Xtra-deep\coal-generic	3.0299E-3	1.2550E-3	generic
coal-ST-S	2.9353E-3	584.39E-6	Sweden
truck+semi-trailer-city-1980s	2.9239E-3	587.91E-3	local
truck-city-1980s-14-20 tons	2.8426E-3	571.99E-3	local
truck+trailer-rural-1980s-32-40 tons	2.8209E-3	567.23E-3	local
oil-heavy-ST-S	2.7796E-3	553.39E-6	Sweden
truck-rural-1980s-20-28 tons	2.7082E-3	544.94E-3	local
pipeline\gas-CAN	2.6164E-3	4.2127E-6	Canada
truck-rural-1980s-14-20 tons	2.5925E-3	521.68E-3	local
Xtra-offshore\crude-oil-generic	2.5711E-3	594.93E-6	generic
truck+semi-trailer-city-EURO 2	2.5579E-3	514.31E-3	local
gas-GT-USA	2.4691E-3	12.436E-3	USA
truck-highway-1980s-20-28 tons	2.4540E-3	493.80E-3	local
truck-city-1980s-20-28 tons	2.3330E-3	469.44E-3	local
Xtra-onshore-tertiary\oil-crude-D	2.1487E-3	6.5728E-3	Germany
truck-city-EURO 1-<7.5 tons	2.1333E-3	429.28E-3	local
truck+trailer-city-1980s-32-40 tons	.0514E-3	412.50E-3	local
truck+semi-trailer-city-EURO 1	2.0217E-3	406.50E-3	local
truck+trailer-rural-1980s-<28 tons	1.9899E-3	400.13E-3	local
truck-highway-1980s-14-20 tons	1.9442E-3	391.23E-3	local
Xtra-onshore-secondory\crude-oil-generic	1.9381E-3	448.46E-6	generic
truck-rural-EURO 1-<7.5 tons	1.8842E-3	379.15E-3	local
truck+trailer-highway-EURO 1-28-32 tons	1.8276E-3	367.50E-3	local
truck-rural-EURO 1-20-28 tons	1.7190E-3	345.91E-3	local
truck+trailer-highway-EURO 1-<28 tons	1.6666E-3	335.13E-3	local
truck+trailer-rural-1980s-28-32 tons	1.5931E-3	320.34E-3	local
truck+trailer-rural-EURO 1-32-40 tons	1.5919E-3	320.09E-3	local
truck-highway-EURO 1-20-28 tons	1.5573E-3	313.36E-3	local
truck+trailer-city-1980s-<28 tons	1.5271E-3	307.07E-3	local
truck-city-EURO 1-20-28 tons	1.4809E-3	297.99E-3	local
truck-city-EURO 2-<7.5 tons	1.4672E-3	295.23E-3	local
truck-city-1980s-7.5-14 tons	1.4378E-3	289.32E-3	local
truck-rural-1980s-7.5-14 tons	1.3347E-3	268.57E-3	local
truck-highway-EURO 1-<7.5 tons	1.3306E-3	267.75E-3	local
truck-rural-EURO 2-20-28 tons	1.3284E-3	267.31E-3	local
truck+trailer-city-1980s-28-32 tons	1.3282E-3	267.08E-3	local
truck-rural-EURO 2-14-20 tons	1.2991E-3	261.41E-3	local
truck-rural-EURO 2-<7.5 tons	1.2962E-3	260.83E-3	local
wood-ST-small-D	1.2526E-3	60.374E-3	Germany
truck+trailer-highway-EURO 2-28-32 tons	1.2263E-3	246.59E-3	local
truck-highway-EURO 2-20-28 tons	1.2034E-3	242.16E-3	local
truck+trailer-rural-EURO 2-32-40 tons	1.2011E-3	241.52E-3	local
truck-city-EURO 1-14-20 tons	1.1968E-3	240.82E-3	local
coal-ST-RSA-Arnot	1.1643E-3	5.5208E-3	South Africa
truck+trailer-highway-EURO 2-<32 tons	1.1626E-3	233.78E-3	local
truck+trailer-city-EURO 1-32-40 tons	1.1573E-3	232.72E-3	local
truck-city-EURO 2-20-28 tons	1.1443E-3	230.25E-3	local
truck-highway-1980s-7.5-14 tons	1.0965E-3	220.64E-3	local
truck-rural-EURO 1-14-20 tons	1.0927E-3	219.87E-3	local
oil-naphtha-boiler-D	1.0032E-3	196.81E-3	Germany
oil-heavy-boiler-NL	991.74E-6	266.80E-6	Netherlands

oil-heavy-ST-I	971.43E-6	2.9172E-3	Italy
truck-highway-EURO 2-<7.5 tons	915.41E-6	184.20E-3	local
gas-GT-S	899.97E-6	179.17E-6	Sweden
waste-ST-USA	878.20E-6	4.2861E-3	USA
truck+trailer-city-EURO 2-32-40 tons	873.18E-6	175.58E-3	local
coal-ST-UK	872.77E-6	2.6215E-3	United Kingdom
truck-city-EURO 2-14-20 tons	835.74E-6	168.17E-3	local
truck-highway-EURO 1-14-20 tons	819.13E-6	164.83E-3	local
coal-ST-E	784.11E-6	2.3547E-3	Spain
truck+trailer-rural-EURO 1-<28 tons	768.25E-6	154.48E-3	local
gas-CC-DK	767.23E-6	295.37E-6	Denmark
refinery\oil-heavy-D	720.27E-6	934.79E-6	Germany
train-dieselmotor-generic	685.72E-6	199.33E-6	generic
truck+trailer-rural-EURO 1-28-32 tons	681.82E-6	137.10E-3	local
truck+trailer-highway-1970s-<28 tons	652.77E-6	131.26E-3	local
truck-city-1970s-<7.5 tons	641.23E-6	129.03E-3	local
gas-CC-UK	620.97E-6	1.8652E-3	United Kingdom
oil-heavy-ST-DK	594.89E-6	229.02E-6	Denmark
truck+trailer-highway-1970s-32-40 tons	592.92E-6	119.24E-3	local
truck+trailer-city-EURO 1-<28 tons	589.88E-6	118.61E-3	local
truck+trailer-city-EURO 1-28-32 tons	568.47E-6	114.31E-3	local
truck-rural-1970s-<7.5 tons	565.80E-6	113.85E-3	local
truck+trailer-highway-1970s-28-32 tons	541.04E-6	108.79E-3	local
truck+trailer-rural-EURO 2-<28 tons	534.65E-6	107.51E-3	local
truck-city-EURO 1-7.5-14 tons	521.95E-6	105.03E-3	local
coal-ST-UK-with-FGD	513.23E-6	1.5416E-3	United Kingdom
Xtra-surface\coal-generic	486.70E-6	201.59E-6	generic
truck-rural-EURO 1-7.5-14 tons	484.70E-6	97.532E-3	local
truck+trailer-rural-EURO 2-28-32 tons	457.49E-6	91.991E-3	local
Xtra-surface\lignite-D-Lausitz	455.72E-6	4.0128E-3	Germany
lignite-ST-GR	439.83E-6	1.3208E-3	Greece
truck+trailer-city-EURO 2-<28 tons	410.26E-6	82.495E-3	local
oil-heavy-ST-USA	408.25E-6	1.9925E-3	USA
gas-CC-I	404.59E-6	1.2150E-3	Italy
truck-highway-1970s-<7.5 tons	399.74E-6	80.437E-3	local
truck-highway-EURO 1-7.5-14 tons	398.23E-6	80.132E-3	local
truck+trailer-city-EURO 2-28-32 tons	381.40E-6	76.692E-3	local
truck+semi-trailer-highway-1970s	377.93E-6	75.999E-3	local
truck-city-EURO 2-7.5-14 tons	368.88E-6	74.227E-3	local
coal-ST-F-Import	362.08E-6	1.0873E-3	France
truck-city-1970s-14-20 tons	360.34E-6	72.508E-3	local
truck-rural-EURO 2-7.5-14 tons	342.62E-6	68.942E-3	local
Refinery\diesel-generic	331.68E-6	76.482E-6	generic
coal-ST-I	329.36E-6	989.07E-6	Italy
truck-rural-1970s-14-20 tons	328.41E-6	66.084E-3	local
waste-ST-DK	315.10E-6	121.31E-6	Denmark
truck+trailer-rural-1970s-<28 tons	291.34E-6	58.582E-3	local
truck-highway-EURO 2-7.5-14 tons	281.48E-6	56.641E-3	local
oil-heavy-ST-UK	273.20E-6	820.62E-6	United Kingdom
truck-city-1970s-7.5-14 tons	256.98E-6	51.710E-3	local
coal-ST-SF	250.05E-6	751.03E-6	Finland
truck-highway-1970s-14-20 tons	246.31E-6	49.563E-3	local
truck-rural-1970s-7.5-14 tons	238.47E-6	47.985E-3	local
refinery\oil-heavy-CAN	236.63E-6	698.96E-9	Canada
truck+trailer-rural-1970s-32-40 tons	223.36E-6	44.913E-3	local
truck+trailer-city-1970s-<28 tons	223.10E-6	44.860E-3	local
refinery\liquid gas	201.90E-6	601.78E-6	Germany
truck+trailer-rural-1970s-28-32 tons	201.87E-6	40.592E-3	local
truck-highway-1970s-7.5-14 tons	195.97E-6	39.433E-3	local
oil-heavy-boiler-S	191.63E-6	38.151E-6	Sweden

Xtra-surface\lignite-D-Leipzig	168.80E-6	1.1995E-3	Germany
truck+trailer-city-1970s-28-32 tons	168.36E-6	33.855E-3	local
truck+semi-trailer-rural-1970s	167.83E-6	33.751E-3	local
truck+trailer-city-1970s-32-40 tons	162.47E-6	32.670E-3	local
coal-ST-P	159.94E-6	480.39E-6	Portugal
truck-rural-1970s-20-28 tons	151.14E-6	30.412E-3	local
truck-highway-1970s-20-28 tons	136.92E-6	27.552E-3	local
geothermal-ST-CAN	132.69E-6	1.3020E-6	Canada
truck-city-1970s-20-28 tons	130.30E-6	26.219E-3	local
oil-heavy-ST-E	116.64E-6	350.27E-6	Spain
coal-ST-IRL	109.95E-6	330.24E-6	Ireland
metal\copper-D-primary	109.27E-6	2.1817E-3	Germany
truck+semi-trailer-city-1970s	108.92E-6	21.901E-3	local
gas-CC-E	106.13E-6	318.72E-6	Spain
Xtra-deep\coal-E	104.07E-6	312.50E-6	Spain
waste-ST-SF	98.758E-6	296.62E-6	Finland
coal-ST-A	93.867E-6	281.89E-6	Austria
Xtra-deep\coal-UK	91.975E-6	276.17E-6	United Kingdom
Xtra-onshore-tertiary\oilgas	89.422E-6	276.19E-6	Germany
gas-GT-F	82.535E-6	247.85E-6	France
compressor-GT-USA	81.244E-6	415.26E-6	USA
oil-heavy-ST-GR	79.916E-6	239.99E-6	Greece
oil-heavy-ST-F	79.600E-6	239.04E-6	France
gas-CC-B	73.181E-6	219.76E-6	Belgium
oil-heavy-boiler-I	66.987E-6	201.15E-6	Italy
Refinery\oil-products-generic	62.598E-6	14.486E-6	generic
waste-ST-UK	59.406E-6	178.44E-6	United Kingdom
oil-heavy-ST-P	58.714E-6	176.35E-6	Portugal
waste-ST-I	58.277E-6	175.01E-6	Italy
truck-rural-East-7.5-14 tons	49.500E-6	9.9605E-3	local
truck+trailer-rural-East-<28 tons	49.327E-6	9.9186E-3	local
refinery\oil-lite-NOR	47.717E-6	65.330E-9	Norway
gas-CC-IRL	47.285E-6	142.02E-6	Ireland
conversion\coke-D	44.634E-6	7.1506E-6	Germany
gas-CC-A	43.121E-6	129.49E-6	Austria
gas-CC-SF	41.302E-6	124.05E-6	Finland
oil-heavy-boiler-DK	41.013E-6	15.789E-6	Denmark
Truck-very-big-diesel-rural-generic	30.051E-6	7.2215E-6	generic
oil-heavy-ST-IRL	27.197E-6	81.686E-6	Ireland
oil-heavy-ST-A	26.052E-6	78.235E-6	Austria
waste-ST-F	24.567E-6	73.775E-6	France
truck+trailer-city-East-<28 tons	24.205E-6	4.8671E-3	local
gas-CC-P	23.115E-6	69.425E-6	Portugal
Xtra-onshore\gas-USA	22.846E-6	116.56E-6	USA
processing\gas-USA	22.822E-6	116.65E-6	USA
waste-ST-E	22.535E-6	67.672E-6	Spain
truck-city-East-7.5-14 tons	22.263E-6	4.4798E-3	local
oil-heavy-boiler-UK	18.877E-6	56.690E-6	United Kingdom
refinery\oil-products-EU	18.123E-6	54.430E-6	EU
xtra-onshore-secondary\oil-crude-NL	17.526E-6	4.7148E-6	Netherlands
forestry\dieselmotor-100% (end)	14.302E-6	866.32E-6	Germany
waste-ST-P	13.798E-6	41.444E-6	Portugal
oil-heavy-ST-B	13.719E-6	41.198E-6	Belgium
Xtra-surface\lignite-GR	13.654E-6	41.000E-6	Greece
geothermal-ST-USA	12.608E-6	61.535E-6	USA
truck-rural-East-<7.5 tons	11.885E-6	2.3916E-3	local
oil-heavy-ST-SF	11.828E-6	35.527E-6	Finland
gas-CC-GR	11.259E-6	33.811E-6	Greece
waste-ST-B	11.120E-6	33.392E-6	Belgium
Xtra-offshore\gas-DK	10.333E-6	7.6714E-6	Denmark

coal-cogen-BP-FGD-D-Chem-el (proportional)	8.7469E-6	1.7160E-3	Germany
oil-heavy-boiler-E	8.0540E-6	24.186E-6	Spain
truck+trailer-highway-East-<28 tons	7.9331E-6	1.5952E-3	local
Xtra-offshore\gas-UK	7.2215E-6	21.688E-6	United Kingdom
truck-highway-East-7.5-14 tons	7.1723E-6	1.4432E-3	local
processing\gas-DK	6.4582E-6	4.7946E-6	Denmark
oil-heavy-boiler-F	6.3117E-6	18.954E-6	France
geothermal-ST-I	6.2309E-6	18.712E-6	Italy
oil-heavy-boiler-GR	5.5381E-6	16.630E-6	Greece
truck-city-East-<7.5 tons	5.2466E-6	1.0557E-3	local
processing\gas-UK	4.5134E-6	13.555E-6	United Kingdom
oil-heavy-boiler-P	4.0451E-6	12.149E-6	Portugal
forestry-raising\spruce-abs.dry	3.9386E-6	238.57E-6	Germany
refinery\oil-heavy-NL	3.9295E-6	1.0571E-6	Netherlands
processing\gas-I	3.0491E-6	9.1566E-6	Italy
compressor-GT-DK	2.9453E-6	1.1353E-6	Denmark
coal-cogen-SE-D-Chem-el (proportional)	8101E-6	51.29E-6	Germany
gas-CC-cogen-big-D-Chem-el (proportional)	2.7631E-6	542.07E-6	Germany
waste-ST-A	2.7158E-6	8.1557E-6	Austria
compressor-GT-UK	2.3834E-6	7.1579E-6	United Kingdom
forestry\2-stroke-ICE-100% (end)	2.3784E-6	144.06E-6	Germany
gas-GT-ALG	2.3561E-6	7.0774E-6	Algeria
Xtra-onshore\gas-I	2.2869E-6	6.8674E-6	Italy
waste-ST-IRL	2.0052E-6	6.0225E-6	Ireland
oil-heavy-boiler-IRL	1.8737E-6	5.6267E-6	Ireland
oil-heavy-boiler-A	1.7961E-6	5.3936E-6	Austria
pipeline\gas-USA	1.7902E-6	9.1502E-6	USA
truck-highway-east-<7.5 tons	1.7814E-6	358.45E-6	local
compressor-GT-I	1.6283E-6	4.8900E-6	Italy
forestry\debarker-100% (end)	1.6143E-6	97.784E-6	Germany
Xtra-surface\coal-UK	1.3828E-6	4.1522E-6	United Kingdom
wood-logs-boiler-D-wood-manufacturing	1.3510E-6	81.835E-6	Germany
waste-ST-GR	1.2856E-6	3.8606E-6	Greece
gas-boiler-DK	1.0421E-6	773.70E-9	Denmark
oil-heavy-boiler-B	945.15E-9	2.8381E-6	Belgium
oil-heavy-boiler-SF	814.93E-9	2.4476E-6	Finland
compressor-GT-F	786.81E-9	2.3628E-6	France
refinery\oil-heavy-S	786.77E-9	156.63E-9	Sweden
diesel motor-UK	751.17E-9	2.2583E-6	United Kingdom
gas-boiler-UK	728.32E-9	2.1873E-6	United Kingdom
Xtra-onshore\gas-ALG	662.82E-9	1.9906E-6	Algeria
processing\gas-ALG	662.82E-9	1.9906E-6	Algeria
Xtra-offshore\gas-IRL	549.89E-9	1.6516E-6	Ireland
xtra-onshore-secondary\oil-crude-I	490.27E-9	1.4722E-6	Italy
gas-boiler-I	474.47E-9	1.4248E-6	Italy
compressor-GT-E	426.65E-9	1.2812E-6	Spain
processing\gas-IRL	343.68E-9	1.0322E-6	Ireland
refinery\oil-heavy-I	274.79E-9	825.18E-9	Italy
xtra-onshore-secondary\oil-crude-GR	262.25E-9	787.52E-9	Greece
compressor-GT-IRL	181.49E-9	545.10E-9	Ireland
compressor-GT-A	173.39E-9	520.69E-9	Austria
refinery\oil-heavy-DK	168.38E-9	64.825E-9	Denmark
compressor-GT-SF	158.34E-9	475.57E-9	Finland
xtra-onshore-secondary\oil-crude-E	147.18E-9	441.98E-9	Spain
compressor-GT-ALG	144.41E-9	433.67E-9	Algeria
forestry\helicopter-100% (end)	113.99E-9	6.9047E-6	Germany
compressor-GT-P	92.919E-9	279.09E-9	Portugal
geothermal-ST-P	79.789E-9	239.65E-9	Portugal
refinery\oil-heavy-UK	77.501E-9	232.75E-9	United Kingdom

processing\gas-A	71.429E-9	214.50E-9	Austria
gas-boiler-IRL	55.459E-9	166.57E-9	Ireland
Xtra-onshore\gas-A	53.572E-9	160.88E-9	Austria
pipeline\gas-DK	53.503E-9	20.624E-9	Denmark
gas-boiler-ALG	46.695E-9	140.24E-9	Algeria
pipeline\gas-UK	43.295E-9	130.03E-9	United Kingdom
compressor-GT-GR	43.162E-9	129.62E-9	Greece
pipeline\gas-I	35.880E-9	107.75E-9	Italy
refinery\oil-heavy-E	32.997E-9	99.092E-9	Spain
refinery\oil-heavy-F	22.736E-9	68.275E-9	France
refinery\oil-heavy-GR	22.614E-9	67.909E-9	Greece
plastics\plastic-generic	18.239E-9	4.3828E-9	generic
refinery\oil-heavy-P	16.608E-9	49.880E-9	Portugal
pipeline\gas-F	14.293E-9	42.921E-9	France
gas-boiler-A	11.115E-9	33.378E-9	Austria
liquefaction\LNG-ALG	10.120E-9	30.391E-9	Algeria
xtra-onshore-tertiary\oil-crude-F	9.8579E-9	29.601E-9	France
pipeline\gas-E	9.4011E-9	28.232E-9	Spain
refinery\oil-heavy-IRL	7.4393E-9	22.339E-9	Ireland
refinery\oil-heavy-A	7.3740E-9	22.144E-9	Austria
pipeline\gas-B	6.0202E-9	18.079E-9	Belgium
pipeline\gas-NL->B	6.0202E-9	18.078E-9	Netherlands
refinery\oil-heavy-B	3.8805E-9	11.653E-9	Belgium
pipeline\gas-A	3.8206E-9	11.473E-9	Austria
pipeline\gas-ALG	3.4971E-9	10.502E-9	Algeria
refinery\oil-heavy-SF	3.3458E-9	10.049E-9	Finland
pipeline\gas-IRL	3.2968E-9	9.9019E-9	Ireland
pipeline\gas-SF	2.8762E-9	8.6389E-9	Finland
pipeline\gas-P	2.0474E-9	6.1495E-9	Portugal
pipeline\gas-GR	784.1E-12	2.3546E-9	Greece
pipeline\gas-D-export	286.5E-12	860.5E-12	Germany
wood-chips-heat plant-D 1 MW'NSW	0.0000000	132.53669	Australia
Xtra-plantation\wood-short-rotation-D	0.0000000	212.19251	Germany
refinery\oil-heavy-USA	126.01E-9	2.6353E-6	USA
Xtra-onshore-tertiary\oil-crude-USA	726.74E-9	6.5501E-6	USA
refinery\oil-lite-USA	3.4898E-6	29.932E-6	USA
Xtra-surface\lignite-PL	5.0379E-6	464.02E-9	Poland
gas-boiler-USA	10.042E-6	132.33E-6	USA
Xtra-offshore-primary\oil-crude-USA	56.669E-6	510.75E-6	USA
Xtra-offshore-secondary\oil-crude-USA	57.577E-6	518.94E-6	USA
oilgas-boiler-USA	315.06E-6	2.8396E-3	USA
oil-heavy-boiler-USA	881.22E-6	7.9378E-3	USA
coal-ST-RSA	13.549E-3	43.516E-6	South Africa
lignite-ST-big-PL	16.299E-3	1.5012E-3	Poland
coal-ST-PL-retrofit	22.095E-3	2.0350E-3	Poland
Xtra-deep\coal-PL	25.742E-3	2.4181E-3	Poland
train-diesel-freight-USA	30.186E-3	2.5066E-3	USA
coal-ST-USA	43.005E-3	60.150E-3	USA
ship-freight-D-domestic	69.815E-3	42.661E-3	Germany
Xtra-deep\coal-RSA	154.04E-3	495.02E-6	South Africa
Xtra-mix\coal-USA	268.41E-3	22.327E-3	USA
Xtra-deep\coal-D	572.50E-3	4.3050113	Germany
coal-cogen-SE-D-Chem-th (proportional)	3.0840328	656.60E-3	Germany
gas-CC-cogen-big-D-Chem-th (proportional)	12.841226	2.7339484	Germany
coal-cogen-BP-FGD-D-Chem-th (proportional)	51.339017	10.930282	Germany

Appendix 5. Comparison of greenhouse gas emissions in option 5 and option 10[6]

Process	Greenhouse gas emissions (tonnes in CO_2 equivalents) Option 1	Option 6	Location
Sum	488.979E3	3.44065E3	
coal-boiler-AUS'NSW	464.292E3	0.0000000	Australia
Xtra-surface\coal-AUS	14.2057E3	1.2983E-3	Australia
coal-ST-AUS	3.24687E3	34.144E-3	Australia
bagasse-ST-FJ-FSC'NSW	2.44409E3	2.44409E3	Fiji
train-diesel-freight-AUS	1.80809E3	7.0174E-3	Australia
diesel motor-AUS	1.20633E3	693.89E-6	Australia
chem-inorg\nitric acid	480.81936	101.78942	Germany
gas-GT-AUS	276.76881	2.9130E-3	Australia
oil-heavy-boiler-AUS	221.05574	620.38E-6	Australia
chem-inorg\ammonia	193.61647	41.070017	Germany
waste-ST-AUS	114.46232	1.2037E-3	Australia
gas-boiler-D	93.137446	21.218700	Germany
blasting (ANFO)	45.994090	582.31E-6	generic
oil-heavy-ST-AUS	45.879257	482.47E-6	Australia
metal\pig-iron-D	34.598999	5.5441665	Germany
xtra-onshore-primary\oil-crude-OPEC	31.255357	3.5132497	OPEC
ship (ocean)	25.667777	2.8969298	generic
Xtra-offshore-secondary\oil-CAN	18.734619	291.53E-6	Canada
Xtra-offshore-primary\oil-crude-CAN	18.439031	286.93E-6	Canada
compressor-GT-GUS	16.931180	4.4046713	CIS
diesel motor-CAN	14.297078	25.740E-3	Canada
lignite-ST-rhine	13.968133	56.140243	Germany
nonmetallic minerals\cement clinker	12.999493	802.21E-3	Germany
gas-ST-GUS	12.528400	1.0183864	CIS
hydro-dam-Tropics	12.451439	79.787E-3	Tropics
metal\aluminium-CIS	12.193283	16.695E-3	CIS
diesel motor-OPEC	12.018872	1.3404689	OPEC
oil-heavy-boiler-OPEC	12.006346	975.67E-3	OPEC
coal-ST-CIS	11.998732	975.33E-3	CIS
metal\aluminium-D	8.3044303	11.370E-3	Germany
metal\aluminium-Tropics	6.9095272	9.4604E-3	Tropics
pipeline\gas-CIS	6.7853012	1.7651772	CIS
compressor-GT-AUS	5.3142881	93.328E-6	Australia
metal\aluminium-AUS	4.8773133	6.6780E-3	Australia
gas-CC-CAN	4.6667407	910.41E-6	Canada
gas-boiler-CAN	4.4842402	13.857E-3	Canada
coal-ballast-ST-D	4.0299183	12.089342	Germany
Xtra-onshore\gas-GUS	3.9427640	941.13E-3	CIS
oil-heavy-ST-CIS	3.9002240	317.03E-3	CIS
diesel motor-GUS	3.7248184	7.8141882	CIS
processing\sinter-D	3.6135709	579.04E-3	Germany
heat-process-cement-D-coal-100% (end)	3.4187937	210.81E-3	Germany
metal\aluminium-NOR	3.2515422	4.4520E-3	Norway
compressor-GT-NOR	2.8614524	751.22E-3	Norway
nonmetallic minerals\CaO-GGR-kiln	2.8302549	303.30E-3	Germany
processing\gas-AUS	2.4615718	43.230E-6	Australia
Xtra-onshore\gas-AUS	2.4601484	43.230E-6	Australia
coal-boiler-GUS	2.4410593	3.3421E-3	CIS

[6] In option 1, energy derived from coal and bagasse in the baseline scenario is 50% and 50% respectively while the proportion of energy derived from woodchips and bagasse is 50% and 50% respectively in option 6 under the mitigation scenario.

heat-process-cement-D-lignite-briquettes-rhine-100% (end)	2.3235847	143.28E-3	Germany
Xtra-onshore-secondary\oil-crude-OPEC	2.2666346	254.78E-3	OPEC
oil-heavy-boiler-Caribbean	2.2511312	3.0817E-3	Caribbean
oil-heavy-boiler-GUS	2.1864822	1.4284979	CIS
gas-boiler-AUS	2.1288158	1.9631E-3	Australia
processing\gas-CIS	1.8921202	451.65E-3	CIS
Xtra-offshore-secondary\oil-crude-AUS	1.5776602	6.5145E-6	Australia
gas-boiler-GUS	1.5657222	217.73E-3	CIS
Xtra-offshore-primary\oil-crude-AUS	1.5527685	6.4117E-6	Australia
Xtra-mix\coal-CIS	1.5028785	99.163E-3	CIS
lignite-ST-D-Lausitz-retrofit	1.3916235	12.693798	Germany
Xtra-onshore\oil-crude-CIS	1.3337260	3.0158691	CIS
compressor-GT-D	1.2734993	331.29E-3	Germany
coal-ST-D	1.2192284	53.080325	Germany
coal-boiler-AUS	1.1626640	1.5918E-3	Australia
waste-ST-D	1.1624989	4.1883723	Germany
Xtra-offshore\gas-NOR	1.0531699	276.49E-3	Norway
oil-heavy-boiler-CAN	1.0476783	2.6379E-3	Canada
heat-process-cement-D-oil-heavy-100% (end)	963.06E-3	59.385E-3	Germany
oil-lite-boiler-D	861.37E-3	1.6590E-3	Germany
refinery\oil-lite-AUS	836.21E-3	2.2533E-6	Australia
diesel motor generic	791.79E-3	182.53E-3	generic
heat-process-CaO-D-gas-100% (end)	772.25E-3	82.756E-3	Germany
propane-boiler-D	765.64E-3	2.2797922	Germany
coal-ST-CAN	710.34E-3	6.9700E-3	Canada
lignite-ST-D-Leipzig	695.64E-3	4.9429760	Germany
coal-boiler-Tropics	692.46E-3	948.06E-6	Tropics
gas-CC-D	681.72E-3	23.771E-3	Germany
processing\gas-NOR	658.24E-3	172.81E-3	Norway
compressor-GT-NL	631.73E-3	164.36E-3	Netherlands
diesel motor-Tropics	624.25E-3	854.59E-6	Tropics
nonmetallic minerals\CaO-kiln	499.49E-3	54.192E-3	Germany
gas-GT-GUS	482.81E-3	115.24E-3	CIS
oil-heavy-boiler-D	478.20E-3	1.4239077	Germany
Xtra-deep\coal-D-Ballast	468.52E-3	1.4055779	Germany
oil-lite-boiler-Tropics	467.38E-3	639.90E-6	Tropics
diesel motor-D	457.73E-3	158.08921	Germany
lignite-ST-D-Lausitz	449.64E-3	3.5264090	Germany
dieselmotor-powerplant-Caribbean	442.06E-3	605.16E-6	Caribbean
train-diesel-freight-BRA	431.60E-3	69.160E-3	Brazil
gas-GT-NOR	382.81E-3	254.81E-3	Norway
Xtra-onshore\gas-NL	381.57E-3	99.275E-3	Netherlands
processing\gas-NL	381.57E-3	99.275E-3	Netherlands
lignite-boiler-FBC-D-rhine	360.89E-3	22.254E-3	Germany
heat-process-CaO-D-coal-100% (end)	328.73E-3	35.665E-3	Germany
oi-lite-boiler-AUS	312.99E-3	428.52E-6	Australia
train-diesel-freight-CIS	288.24E-3	394.63E-6	CIS
diesel motor-Caribbean	277.56E-3	379.97E-6	Caribbean
processing\gas-D	258.83E-3	67.333E-3	Germany
Xtra-onshore\gas-D	258.83E-3	67.333E-3	Germany
oil-heavy-boiler-BRA	237.36E-3	38.034E-3	Brazil
oil-lite-boiler-NOR	213.10E-3	291.76E-6	Norway
compressor-GT-CAN	180.01E-3	289.87E-6	Canada
nonmetallic minerals\clay bricks	172.03E-3	27.573E-3	Germany
oilgas-boiler-D	161.92E-3	495.34E-3	Germany
pipeline\gas-AUS	161.00E-3	2.8256E-6	Australia
gas-boiler-S	142.89E-3	22.897E-3	Sweden
oil-heavy-boiler-big-generic	141.26E-3	32.687E-3	generic

gas-boiler-NOR	133.37E-3	103.64E-3	Norway
coal-boiler-FBC-D	119.01E-3	162.93E-6	Germany
gas-ST-D	116.07E-3	5.5941435	Germany
gas-CC-NL	111.35E-3	29.953E-3	Netherlands
coal-ST-NL	110.31E-3	29.673E-3	Netherlands
coal-boiler-Caribbean	108.13E-3	148.02E-6	Caribbean
Xtra-offshore-secondary\oil-EU	107.68E-3	323.43E-3	EU
Xtra-offshore-primary\oil-crude-EU	105.99E-3	318.33E-3	EU
waste-ST-CAN	103.22E-3	1.0128E-3	Canada
metal\steel-D-EAF-new	85.659E-3	13.597E-3	Germany
processing\gas-CAN	81.817E-3	131.75E-6	Canada
Xtra-onshore\gas-CAN	81.817E-3	131.66E-6	Canada
diesel motor-EU	81.281E-3	244.11E-3	EU
train-diesel-freight-Tropics	73.481E-3	100.60E-6	Tropics
refinery\oil-heavy-AUS	70.816E-3	292.26E-9	Australia
oil-heavy-ST-CAN	66.833E-3	655.78E-6	Canada
gas-CC-D-East	63.855E-3	2.8702535	Germany
train-diesel-freight-CAN	62.635E-3	10.037E-3	Canada
coal-ST-big-generic	56.196E-3	23.276E-3	generic
gas-boiler-NL	52.631E-3	13.693E-3	Netherlands
pipeline\gas-NOR	51.979E-3	13.646E-3	Norway
oil-heavy-ST-D	48.675E-3	1.7924193	Germany
heat-process-coking-D-coke	45.875E-3	7.3493E-3	Germany
gas-GT-D	38.718E-3	1.5198924	Germany
chem-inorg\sodium carbonate	32.411E-3	44.372E-6	Germany
pipeline\gas-D	28.063E-3	7.2999E-3	Germany
gas-CC-D-medium	27.291E-3	1.0049786	Germany
coal-ST-D-coast	24.969E-3	1.2034365	Germany
Xtra-surface\coal-CAN	24.501E-3	240.60E-6	Canada
diesel motor-USA	21.762E-3	137.34E-3	USA
truck+semi-trailer-highway-EURO 2	20.367E-3	4.0957296	local
truck+semi-trailer-highway-1980s	19.949E-3	4.0115844	local
Xtra-onshore-primary\crude-oil-generic	19.381E-3	4.4846E-3	generic
oil-heavy-ST-NL	17.942E-3	4.8266E-3	Netherlands
refinery\oil-lite-D	17.448E-3	54.976E-3	Germany
waste-ST-NL	17.249E-3	4.6402E-3	Netherlands
coal-ST-NOR	16.295E-3	252.45E-6	Norway
truck+semi-trailer-highway-EURO 1	15.470E-3	3.1108276	local
train-diesel-freight-Caribbean	15.043E-3	20.594E-6	Caribbean
refinery\oil-heavy-OPEC	13.705E-3	1.3383E-3	OPEC
pipeline\Gas-NL	10.977E-3	2.8559E-3	Netherlands
oil-heavy-ST-small-generic	10.805E-3	2.5001E-3	generic
truck+trailer-highway-1980s-32-40 tons	9.3568E-3	1.8817804	local
coal-ST-RSA-Matimba	8.2202E-3	38.978E-3	South Africa
coal-ST-RSA-Duvha	7.9666E-3	37.775E-3	South Africa
coal-ST-RSA-Kendal	7.6281E-3	36.170E-3	South Africa
truck-city-1980s-<7.5 tons	6.5376E-3	1.3155021	local
truck+semi-trailer-rural-1980s	6.4574E-3	1.2985405	local
truck+semi-trailer-rural-EURO 2	5.9799E-3	1.2025295	local
truck-rural-1980s-<7.5 tons	5.7701E-3	1.1610661	local
truck+trailer-highway-1980s-<28 tons	5.4411E-3	1.0940953	local
coal-ST-RSA-Matla	5.3539E-3	25.387E-3	South Africa
truck+trailer-highway-1980s-28-32 tons	5.3377E-3	1.0733098	local
coal-ST-RSA-Tutuka	5.3036E-3	25.148E-3	South Africa
coal-ST-B	5.2934E-3	2.5663E-3	Belgium
truck+trailer-highway-EURO 1-32-40 tons	5.2826E-3	1.0623922	local
coal-ST-RSA-Lethabo	5.1237E-3	24.295E-3	South Africa
refinery\oil-heavy-CIS	5.0389E-3	4.7723E-3	CIS
Xtra-surface\lignite-D-rhine	4.9073E-3	16.191E-3	Germany
truck+semi-trailer-rural-EURO 1	4.6533E-3	935.75E-3	local

oil-distillate-GT-small-generic	4.5937E-3	1.0629E-3	generic
coal-ST-RSA-Kriel	4.3905E-3	20.818E-3	South Africa
coal-ST-RSA-Hendrina	4.3652E-3	20.699E-3	South Africa
truck-highway-1980s-<7.5 tons	4.0758E-3	820.15E-3	local
waste-ST-S	4.0360E-3	803.52E-6	Sweden
refinery\oil-lite-CAN	4.0028E-3	9.9501E-6	Canada
truck+trailer-highway-EURO 2-32-40 tons	3.9859E-3	801.61E-3	local
Xtra-deep\coal-generic	3.7874E-3	1.5687E-3	Generic
coal-ST-S	3.6692E-3	730.48E-6	Sweden
truck+semi-trailer-city-1980s	3.6549E-3	734.88E-3	local
truck-city-1980s-14-20 tons	3.5532E-3	714.99E-3	local
truck+trailer-rural-1980s-32-40 tons	3.5262E-3	709.04E-3	local
oil-heavy-ST-S	3.4745E-3	691.74E-6	Sweden
truck-rural-1980s-20-28 tons	3.3852E-3	681.18E-3	local
pipeline\gas-CAN	3.2705E-3	5.2658E-6	Canada
truck-rural-1980s-14-20 tons	3.2407E-3	652.10E-3	local
Xtra-offshore\crude-oil-generic	3.2139E-3	743.66E-6	generic
truck+semi-trailer-city-EURO 2	3.1973E-3	642.89E-3	local
gas-GT-USA	3.0864E-3	15.545E-3	USA
truck-highway-1980s-20-28 tons	3.0675E-3	617.25E-3	local
truck-city-1980s-20-28 tons	2.9162E-3	586.80E-3	local
Xtra-onshore-tertiary\oil-crude-D	2.6859E-3	8.2159E-3	Germany
truck-city-EURO 1-<7.5 tons	2.6667E-3	536.60E-3	local
truck+trailer-city-1980s-32-40 tons	2.5643E-3	515.62E-3	local
truck+semi-trailer-city-EURO 1	2.5271E-3	508.12E-3	local
truck+trailer-rural-1980s-<28 tons	2.4874E-3	500.17E-3	local
truck-highway-1980s-14-20 tons	2.4303E-3	489.03E-3	local
Xtra-onshore-secondory\crude-oil-generic	2.4226E-3	560.57E-6	generic
truck-rural-EURO 1-<7.5 tons	2.3553E-3	473.93E-3	local
truck+trailer-highway-EURO 1-28-32 tons	2.2846E-3	459.38E-3	local
truck-rural-EURO 1-20-28 tons	2.1488E-3	432.39E-3	local
truck+trailer-highway-EURO 1-<28 tons	2.0833E-3	418.91E-3	local
truck+trailer-rural-1980s-28-32 tons	1.9914E-3	400.43E-3	local
truck+trailer-rural-EURO 1-32-40 tons	1.9898E-3	400.11E-3	local
truck-highway-EURO 1-20-28 tons	1.9466E-3	391.71E-3	local
truck+trailer-city-1980s-<28 tons	1.9089E-3	383.83E-3	local
truck-city-EURO 1-20-28 tons	1.8511E-3	372.48E-3	local
truck-city-EURO 2-<7.5 tons	1.8340E-3	369.04E-3	local
truck-city-1980s-7.5-14 tons	1.7973E-3	361.65E-3	local
truck-rural-1980s-7.5-14 tons	1.6683E-3	335.71E-3	local
truck-highway-EURO 1-<7.5 tons	1.6633E-3	334.69E-3	local
truck-rural-EURO 2-20-28 tons	1.6605E-3	334.13E-3	local
truck+trailer-city-1980s-28-32 tons	1.6603E-3	333.85E-3	local
truck-rural-EURO 2-14-20 tons	1.6239E-3	326.76E-3	local
truck-rural-EURO 2-<7.5 tons	1.6203E-3	326.04E-3	local
wood-ST-small-D	1.5658E-3	75.467E-3	Germany
truck+trailer-highway-EURO 2-28-32 tons	1.5329E-3	308.23E-3	local
truck-highway-EURO 2-20-28 tons	1.5043E-3	302.70E-3	local
truck+trailer-rural-EURO 2-32-40 tons	1.5014E-3	301.90E-3	local
truck-city-EURO 1-14-20 tons	1.4960E-3	301.03E-3	local
coal-ST-RSA-Arnot	1.4554E-3	6.9010E-3	South Africa
truck+trailer-highway-EURO 2-<32 tons	1.4533E-3	292.23E-3	local
truck+trailer-city-EURO 1-32-40 tons	1.4467E-3	290.90E-3	local
truck-city-EURO 2-20-28 tons	1.4303E-3	287.81E-3	local
truck-highway-1980s-7.5-14 tons	1.3706E-3	275.80E-3	local
truck-rural-EURO 1-14-20 tons	1.3658E-3	274.83E-3	local
oil-naphtha-boiler-D	1.2540E-3	246.01E-3	Germany
oil-heavy-boiler-NL	1.2397E-3	333.50E-6	Netherlands
oil-heavy-ST-I	1.2143E-3	3.6465E-3	Italy
truck-highway-EURO 2-<7.5 tons	1.1443E-3	230.25E-3	local

gas-GT-S	1.1250E-3	223.97E-6	Sweden
waste-ST-USA	1.0978E-3	5.3576E-3	USA
truck+trailer-city-EURO 2-32-40 tons	1.0915E-3	219.47E-3	local
coal-ST-UK	1.0910E-3	3.2769E-3	United Kingdom
truck-city-EURO 2-14-20 tons	1.0447E-3	210.21E-3	local
truck-highway-EURO 1-14-20 tons	1.0239E-3	206.04E-3	local
coal-ST-E	980.14E-6	2.9434E-3	Spain
truck+trailer-rural-EURO 1-<28 tons	960.31E-6	193.10E-3	local
gas-CC-DK	959.04E-6	369.22E-6	Denmark
refinery\oil-heavy-D	900.34E-6	1.1685E-3	Germany
train-dieselmotor-generic	857.15E-6	249.16E-6	generic
truck+trailer-rural-EURO 1-28-32 tons	852.28E-6	171.38E-3	local
truck+trailer-highway-1970s-<28 tons	815.96E-6	164.07E-3	local
truck-city-1970s-<7.5 tons	801.54E-6	161.29E-3	local
gas-CC-UK	776.21E-6	2.3315E-3	United Kingdom
oil-heavy-ST-DK	743.62E-6	286.28E-6	Denmark
truck+trailer-highway-1970s-32-40 tons	741.15E-6	149.06E-3	local
truck+trailer-city-EURO 1-<28 tons	737.35E-6	148.27E-3	local
truck+trailer-city-EURO 1-28-32 tons	710.59E-6	142.88E-3	local
truck-rural-1970s-<7.5 tons	707.25E-6	142.31E-3	local
truck+trailer-highway-1970s-28-32 tons	676.30E-6	135.99E-3	local
truck+trailer-rural-EURO 2-<28 tons	668.31E-6	134.38E-3	local
truck-city-EURO 1-7.5-14 tons	652.44E-6	131.29E-3	local
coal-ST-UK-with-FGD	641.54E-6	1.9270E-3	United Kingdom
Xtra-surface\coal-generic	608.38E-6	251.99E-6	generic
truck-rural-EURO 1-7.5-14 tons	605.87E-6	121.92E-3	local
truck+trailer-rural-EURO 2-28-32 tons	571.86E-6	114.99E-3	local
Xtra-surface\lignite-D-Lausitz	569.64E-6	5.0160E-3	Germany
lignite-ST-GR	549.79E-6	1.6510E-3	Greece
truck+trailer-city-EURO 2-<28 tons	512.82E-6	103.12E-3	local
oil-heavy-ST-USA	510.32E-6	2.4906E-3	USA
gas-CC-I	505.74E-6	1.5187E-3	Italy
truck-highway-1970s-<7.5 tons	499.68E-6	100.55E-3	local
truck-highway-EURO 1-7.5-14 tons	497.78E-6	100.17E-3	local
truck+trailer-city-EURO 2-28-32 tons	476.75E-6	95.865E-3	local
truck+semi-trailer-highway-1970s	472.41E-6	94.999E-3	local
truck-city-EURO 2-7.5-14 tons	461.10E-6	92.784E-3	local
coal-ST-F-Import	452.60E-6	1.3592E-3	France
truck-city-1970s-14-20 tons	450.42E-6	90.635E-3	local
truck-rural-EURO 2-7.5-14 tons	428.27E-6	86.178E-3	local
Refinery\diesel-generic	414.60E-6	95.603E-6	generic
coal-ST-I	411.70E-6	1.2363E-3	Italy
truck-rural-1970s-14-20 tons	410.52E-6	82.605E-3	local
waste-ST-DK	393.88E-6	151.64E-6	Denmark
truck+trailer-rural-1970s-<28 tons	364.17E-6	73.227E-3	local
truck-highway-EURO 2-7.5-14 tons	351.86E-6	70.801E-3	local
oil-heavy-ST-UK	341.50E-6	1.0258E-3	United Kingdom
truck-city-1970s-7.5-14 tons	321.23E-6	64.638E-3	local
coal-ST-SF	312.56E-6	938.79E-6	Finland
truck-highway-1970s-14-20 tons	307.89E-6	61.954E-3	local
truck-rural-1970s-7.5-14 tons	298.08E-6	59.981E-3	local
refinery\oil-heavy-CAN	295.79E-6	873.70E-9	Canada
truck+trailer-rural-1970s-32-40 tons	279.20E-6	56.141E-3	local
truck+trailer-city-1970s-<28 tons	278.87E-6	56.075E-3	local
refinery\liquid gas	252.37E-6	752.22E-6	Germany
truck+trailer-rural-1970s-28-32 tons	252.34E-6	50.740E-3	local
truck-highway-1970s-7.5-14 tons	244.96E-6	49.291E-3	local
oil-heavy-boiler-S	239.54E-6	47.689E-6	Sweden
Xtra-surface\lignite-D-Leipzig	211.00E-6	1.4994E-3	Germany
truck+trailer-city-1970s-28-32 tons	210.46E-6	42.318E-3	local

truck+semi-trailer-rural-1970s	209.79E-6	42.188E-3	local
truck+trailer-city-1970s-32-40 tons	203.09E-6	40.838E-3	local
coal-ST-P	199.93E-6	600.48E-6	Portugal
truck-rural-1970s-20-28 tons	188.92E-6	38.015E-3	local
truck-highway-1970s-20-28 tons	171.15E-6	34.440E-3	local
geothermal-ST-CAN	165.86E-6	1.6275E-6	Canada
truck-city-1970s-20-28 tons	162.87E-6	32.774E-3	local
oil-heavy-ST-E	145.80E-6	437.84E-6	Spain
coal-ST-IRL	137.44E-6	412.80E-6	Ireland
metal\copper-D-primary	136.58E-6	2.7271E-3	Germany
truck+semi-trailer-city-1970s	136.15E-6	27.376E-3	local
gas-CC-E	132.67E-6	398.40E-6	Spain
Xtra-deep\coal-E	130.08E-6	390.63E-6	Spain
waste-ST-SF	123.45E-6	370.78E-6	Finland
coal-ST-A	117.33E-6	352.36E-6	Austria
Xtra-deep\coal-UK	114.97E-6	345.21E-6	United Kingdom
Xtra-onshore-tertiary\oilgas	111.78E-6	345.24E-6	Germany
gas-GT-F	103.17E-6	309.82E-6	France
compressor-GT-USA	101.56E-6	519.08E-6	USA
oil-heavy-ST-GR	99.896E-6	299.99E-6	Greece
oil-heavy-ST-F	99.500E-6	298.80E-6	France
gas-CC-B	91.476E-6	274.71E-6	Belgium
oil-heavy-boiler-I	83.734E-6	251.44E-6	Italy
Refinery\oil-products-generic	78.248E-6	18.107E-6	generic
waste-ST-UK	74.258E-6	223.05E-6	United Kingdom
oil-heavy-ST-P	73.393E-6	220.44E-6	Portugal
waste-ST-I	72.846E-6	218.76E-6	Italy
truck-rural-East-7.5-14 tons	61.875E-6	12.451E-3	local
truck+trailer-rural-East-<28 tons	61.659E-6	12.398E-3	local
refinery\oil-lite-NOR	59.647E-6	81.662E-9	Norway
gas-CC-IRL	59.106E-6	177.53E-6	Ireland
conversion\coke-D	55.793E-6	8.9382E-6	Germany
gas-CC-A	53.902E-6	161.87E-6	Austria
gas-CC-SF	51.627E-6	155.06E-6	Finland
oil-heavy-boiler-DK	51.266E-6	19.737E-6	Denmark
Truck-very-big-diesel-rural-generic	37.564E-6	9.0269E-6	generic
oil-heavy-ST-IRL	33.996E-6	102.11E-6	Ireland
oil-heavy-ST-A	32.565E-6	97.794E-6	Austria
waste-ST-F	30.709E-6	92.219E-6	France
truck+trailer-city-East-<28 tons	30.256E-6	6.0839E-3	local
gas-CC-P	28.893E-6	86.782E-6	Portugal
Xtra-onshore\gas-USA	28.557E-6	145.70E-6	USA
processing\gas-USA	28.527E-6	145.81E-6	USA
waste-ST-E	28.168E-6	84.590E-6	Spain
truck-city-East-7.5-14 tons	27.829E-6	5.5998E-3	local
oil-heavy-boiler-UK	23.596E-6	70.862E-6	United Kingdom
refinery\oil-products-EU	22.654E-6	68.038E-6	EU
xtra-onshore-secondary\oil-crude-NL	21.907E-6	5.8935E-6	Netherlands
forestry\dieselmotor-100% (end)	17.878E-6	1.0829E-3	Germany
waste-ST-P	17.248E-6	51.805E-6	Portugal
oil-heavy-ST-B	17.148E-6	51.497E-6	Belgium
Xtra-surface\lignite-GR	17.067E-6	51.250E-6	Greece
geothermal-ST-USA	15.760E-6	76.918E-6	USA
truck-rural-East-<7.5 tons	14.857E-6	2.9895E-3	local
oil-heavy-ST-SF	14.786E-6	44.409E-6	Finland
gas-CC-GR	14.073E-6	42.263E-6	Greece
waste-ST-B	13.899E-6	41.740E-6	Belgium
Xtra-offshore\gas-DK	12.916E-6	9.5893E-6	Denmark
coal-cogen-BP-FGD-D-Chem-el (proportional)	10.934E-6	2.1450E-3	Germany

oil-heavy-boiler-E	10.068E-6	30.232E-6	Spain
truck+trailer-highway-East-<28 tons	9.9164E-6	1.9940E-3	local
Xtra-offshore\gas-UK	9.0269E-6	27.109E-6	United Kingdom
truck-highway-East-7.5-14 tons	8.9653E-6	1.8040E-3	local
processing\gas-DK	8.0728E-6	5.9933E-6	Denmark
oil-heavy-boiler-F	7.8896E-6	23.693E-6	France
geothermal-ST-I	7.7887E-6	23.390E-6	Italy
oil-heavy-boiler-GR	.9226E-6	20.788E-6	Greece
truck-city-East-<7.5 tons	6.5582E-6	1.3197E-3	local
processing\gas-UK	5.6418E-6	16.944E-6	United Kingdom
oil-heavy-boiler-P	5.0564E-6	15.187E-6	Portugal
forestry-raising\spruce-abs.dry	4.9232E-6	298.21E-6	Germany
refinery\oil-heavy-NL	4.9118E-6	1.3213E-6	Netherlands
processing\gas-I	3.8114E-6	11.446E-6	Italy
compressor-GT-DK	3.6817E-6	1.4192E-6	Denmark
coal-cogen-SE-D-Chem-el (proportional)	3.5127E-6	689.11E-6	Germany
gas-CC-cogen-big-D-Chem-el (proportional)	3.4539E-6	677.58E-6	Germany
waste-ST-A	3.3948E-6	10.195E-6	Austria
compressor-GT-UK	2.9793E-6	8.9474E-6	United Kingdom
forestry\2-stroke-ICE-100% (end)	2.9730E-6	180.08E-6	Germany
gas-GT-ALG	2.9452E-6	8.8467E-6	Algeria
Xtra-onshore\gas-I	2.8586E-6	8.5843E-6	Italy
waste-ST-IRL	2.5064E-6	7.5282E-6	Ireland
oil-heavy-boiler-IRL	2.3422E-6	7.0334E-6	Ireland
oil-heavy-boiler-A	2.2451E-6	6.7419E-6	Austria
pipeline\gas-USA	2.2377E-6	11.438E-6	USA
truck-highway-east-<7.5 tons	2.2267E-6	448.06E-6	local
compressor-GT-I	2.0354E-6	6.1124E-6	Italy
forestry\debarker-100% (end)	2.0179E-6	122.23E-6	Germany
Xtra-surface\coal-UK	1.7285E-6	5.1902E-6	United Kingdom
wood-logs-boiler-D-wood-manufacturing	1.6888E-6	102.29E-6	Germany
waste-ST-GR	1.6069E-6	4.8257E-6	Greece
gas-boiler-DK	1.3027E-6	967.13E-9	Denmark
oil-heavy-boiler-B	1.1814E-6	3.5476E-6	Belgium
oil-heavy-boiler-SF	1.0187E-6	3.0595E-6	Finland
compressor-GT-F	983.52E-9	2.9535E-6	France
refinery\oil-heavy-S	983.47E-9	195.79E-9	Sweden
diesel motor-UK	938.97E-9	2.8229E-6	United Kingdom
gas-boiler-UK	910.40E-9	2.7341E-6	United Kingdom
processing\gas-ALG	828.52E-9	2.4883E-6	Algeria
Xtra-onshore\gas-ALG	828.52E-9	2.4883E-6	Algeria
Xtra-offshore\gas-IRL	687.36E-9	2.0645E-6	Ireland
xtra-onshore-secondary\oil-crude-I	612.84E-9	1.8403E-6	Italy
gas-boiler-I	593.08E-9	1.7810E-6	Italy
compressor-GT-E	533.31E-9	1.6016E-6	Spain
processing\gas-IRL	429.60E-9	1.2903E-6	Ireland
refinery\oil-heavy-I	343.49E-9	1.0315E-6	Italy
xtra-onshore-secondary\oil-crude-GR	327.81E-9	984.40E-9	Greece
compressor-GT-IRL	226.86E-9	681.37E-9	Ireland
compressor-GT-A	216.74E-9	650.87E-9	Austria
refinery\oil-heavy-DK	210.48E-9	81.031E-9	Denmark
compressor-GT-SF	197.92E-9	594.46E-9	Finland
xtra-onshore-secondary\oil-crude-E	183.98E-9	552.47E-9	Spain
compressor-GT-ALG	180.52E-9	542.09E-9	Algeria
forestry\helicopter-100% (end)	142.49E-9	8.6309E-6	Germany
compressor-GT-P	116.15E-9	348.86E-9	Portugal
geothermal-ST-P	99.736E-9	299.56E-9	Portugal
refinery\oil-heavy-UK	96.876E-9	290.93E-9	United Kingdom
processing\gas-A	89.287E-9	268.13E-9	Austria

gas-boiler-IRL	69.324E-9	208.21E-9	Ireland
Xtra-onshore\gas-A	66.965E-9	201.10E-9	Austria
pipeline\gas-DK	66.879E-9	25.780E-9	Denmark
gas-boiler-ALG	58.369E-9	175.30E-9	Algeria
pipeline\gas-UK	54.119E-9	162.53E-9	United Kingdom
compressor-GT-GR	53.953E-9	162.02E-9	Greece
pipeline\gas-I	44.850E-9	134.69E-9	Italy
refinery\oil-heavy-E	41.247E-9	123.86E-9	Spain
refinery\oil-heavy-F	28.419E-9	85.344E-9	France
refinery\oil-heavy-GR	28.267E-9	84.886E-9	Greece
plastics\plastic-generic	22.799E-9	5.4784E-9	generic
refinery\oil-heavy-P	20.760E-9	62.350E-9	Portugal
pipeline\gas-F	17.866E-9	53.652E-9	France
gas-boiler-A	13.894E-9	41.723E-9	Austria
liquefaction\LNG-ALG	12.650E-9	37.989E-9	Algeria
xtra-onshore-tertiary\oil-crude-F	12.322E-9	37.002E-9	France.
pipeline\gas-E	11.751E-9	35.290E-9	Spain
refinery\oil-heavy-IRL	9.2991E-9	27.924E-9	Ireland
refinery\oil-heavy-A	9.2175E-9	27.680E-9	Austria
pipeline\gas-B	7.5252E-9	22.599E-9	Belgium
pipeline\gas-NL->B	7.5252E-9	22.597E-9	Netherlands
refinery\oil-heavy-B	4.8506E-9	14.566E-9	Belgium
pipeline\gas-A	4.7757E-9	14.342E-9	Austria
pipeline\gas-ALG	4.3714E-9	13.127E-9	Algeria
refinery\oil-heavy-SF	4.1822E-9	12.561E-9	Finland
pipeline\gas-IRL	4.1210E-9	12.377E-9	Ireland
pipeline\gas-SF	3.5953E-9	10.799E-9	Finland
pipeline\gas-P	2.5593E-9	7.6869E-9	Portugal
pipeline\gas-GR	980.1E-12	2.9432E-9	Greece
pipeline\gas-D-export	358.2E-12	1.0756E-9	Germany
wood-chips-heat plant-D 1 MW'NSW	0.0000000	165.67086	Australia
Xtra-plantation\wood-short-rotation-D	0.0000000	265.24064	Germany
refinery\oil-heavy-USA	157.52E-9	3.2941E-6	USA
Xtra-onshore-tertiary\oil-crude-USA	908.43E-9	8.1876E-6	USA
refinery\oil-lite-USA	4.3622E-6	37.415E-6	USA
Xtra-surface\lignite-PL	6.2974E-6	580.03E-9	Poland
gas-boiler-USA	12.553E-6	165.41E-6	USA
Xtra-offshore-primary\oil-crude-USA	70.836E-6	638.44E-6	USA
Xtra-offshore-secondary\oil-crude-USA	71.972E-6	648.67E-6	USA
oilgas-boiler-USA	393.82E-6	3.5495E-3	USA
oil-heavy-boiler-USA	1.1015E-3	9.9222E-3	USA
coal-ST-RSA	16.936E-3	54.395E-6	South Africa
lignite-ST-big-PL	20.374E-3	1.8765E-3	Poland
coal-ST-PL-retrofit	27.618E-3	2.5438E-3	Poland
Xtra-deep\coal-PL	32.178E-3	3.0227E-3	Poland
train-diesel-freight-USA	37.733E-3	3.1332E-3	USA
coal-ST-USA	53.756E-3	75.187E-3	USA
ship-freight-D-domestic	87.268E-3	53.326E-3	Germany
Xtra-deep\coal-RSA	192.55E-3	618.78E-6	South Africa
Xtra-mix\coal-USA	335.51E-3	27.908E-3	USA
Xtra-deep\coal-D	715.63E-3	5.3812641	Germany
coal-cogen-SE-D-Chem-th (proportional)	3.8550410	820.75E-3	Germany
gas-CC-cogen-big-D-Chem-th (proportional)	16.051533	3.4174355	Germany
coal-cogen-BP-FGD-D-Chem-th (proportional)	64.173771	13.662852	Germany

Appendix 6. The data used for the study

Description	Quantity/ Value	Source
Average above ground biomass of camphor laurel	2735.5 tonnes per hectare	Estimates of SFNSW (1999b, 11)
Market price of land – camphor infested	$2500.00	Noted during the field study
Camphor free	$5000.00	
Cost of carbon sequestration	$21.75 per tonne of CO_2	ABARE, 1994,9
Harvesting cost of camphor vegetation	$10.00 per tonne	Estimates of SFNSW (1999a, 2)
On-site processing cost of woodchips	$10.00 per tonne	As above
Transport cost of woodchips	$10.00 per tonne	As above
Delivered price of woodchips	$34.00 per tonne	As above
Plantation establishment cost	$2,300.00 per hectare	Estimates of SFNSW (Lamb, K., SFNSW, per. comm. 05/03/2001
Plantation maintenance cost (fertilizer application at year 2)	$600 per hectare	As above
Annual overhead cost of plantations	$160.00 per hectare	As above
Annual operational costs of power generation in sugar mills	$200,000.00	Estimates of SFNSW, (1999, 30)
Capital cost of the project	$35,000,000.00	Estimates of SFNSW, (1999b, 27)
Thinning products of eucalypt plantations (first thinning at year 10)	Biofuel: 82 m^3 per hectare Sawlog 21 m^3 per hectare	Estimates of SFNSW (Lamb, K., SFNSW, per. comm. 05/03/2001.
Final harvest of eucalypt plantations (year 20)	Biofuel: 79 m^3 per hectare Sawlog 254 m^3 per hectare	As above
Price of camphor timber	$40 per m^3	As above
Price of eucalypt sawlogs	$50 per tonne	ANU Forestry, 2000
Employment benefits/ Cost of salaries and wages	$3,000,000 per annum	Information collected during the field visit